METAZOAN PARASITES OF RODENTS IN NEW ZEALAND

A thesis presented for the degree of Master of Science in Zoology University of Canterbury

by

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CHAPTER 1

INTRODUCTION

The knowledge of rodent parasites and their distribution are important in every country as many of these threaten both human and domestic stock populations either directly or by the diseases transmitted by them. Although the parasites of the rodent species present in New Zealand have been widely studied overseas, the introduction of rodents into New Zealand from a variety of sources has meant that the faunal assemblage infesting these hosts could not be predetermined. The long associations of all four rodent species with man, and his role in their introductions to New Zealand have meant that the normal patterns of zoogeography cannot be expected to operate in the distribution of rodent parasites.

Information on the metazoan parasites of rodents in New Zealand is not extensive. Smit (1965) summarized most of the known flea distributions, Ford-Robertson and Bull (1966) published some information on parasite collections made from Rattus exulans on Little Barrier and Hen Islands and Blakelock and Allen (1959) listed several parasites of Rattus rattus and Rattus norvegicus in the Wellington area. There are several isolated records of mite (Acarina) species occurring on rats and mice and these have been summarized by Whitten (1962), Sweatman (1962) and Spain and Luxton (1971). Beveridge and Daniel (1965) listed two parasite species from Rattus norvegicus and Cairns (1966) recorded the distribution of Trichinella spiralis (Nematoda) in R. norvegicus.

No extensive survey of the parasites of any of the rodent species in New Zealand has previously been published so for this project all four rodent species were collected from as wide a range of localities and habitats as possible. The distributions and incidence of the parasites collected along with the factors influencing them are examined while the relevance of the parasite fauna both biologically and

economically and possible reasons for the composition of the fauna are also considered.

CHAPTER 2

MATERIALS AND METHODS

A. HOSTS

317 rodents were examined individually for ectoparasites and 273 of these were examined for endoparasites. Further pooled samples of ectoparasites were examined from collections made on a number of off-shore islands. The locations of the various collecting stations are shown in Fig. 2 and the rodent species present at each station are shown in Table 1. Details of the rodents examined are summarized in Tables 2 and 3. The host collection methods were varied and the numbers collected by each method are listed, for each locality, in appendix A. Nests from all three species of Rattus were obtained and their arthropod fauna examined after Berlesse funnel extractions and direct examination of nest materials.

B. COLLECTION METHODS

At the time of collection the carcasses were placed in plastic bags which were sealed by tying the top to prevent the escape of ectoparasites. Hosts collected at stations 1, 3-9, 11, 13, 17 and 19-22 were placed in liquid preservative on capture and forwarded for examination. Hosts collected live were killed in the field, using a chloroform box, and transferred immediately to a plastic bag. Few rodents were examined fresh. Most of those not in preservative were deep frozen, to immobilize the ectoparasites, and examined after thawing.

The rodents in liquid preservative were drained for 30-60 minutes before weighing and the recording of standard measurements for host species determination and the assessment of reproductive condition. The remaining hosts were thawed in their plastic bags and the required data then recorded. The criteria used for determining adult and juvenile rats were vaginal perforation and testes position.

With mice these criteria are less reliable and difficult to determine (Gibson, 1970 unpubl.) so the presence of corpora lutea on the ovaries and the visibility of tubules in the cauda epididymus were used.

Isolation of individual hosts was continued throughout all stages of their examination to avoid cross-contaminations of parasites. All plastic bags were scanned under a low power microscope (x 6) and each dissecting tray checked for parasites. Those found were included in that host's fauna. Fleas, lice and mites were frequently recovered in this way especially along the edges of the plastic bags. All trays were washed between use for each host and the contents of all containers were checked by washing these contents through a fine mesh sieve (0.18mm x 0.18mm mesh aperture) and the residue left to soak in 7% potassium hydroxide solution to dissolve any fur present and to clear the ectoparasites. Further details of this technique are given below.

(i) Endoparasite Collection

After recording host data the body wall was cut from just anterior of the anus to the base of the lower jaw. The oesophagus was then cut, close to the stomach, and the alimentary tract posterior to this removed by cutting through the bile duct, mesentaries and blood vessels. The rectum was cut as close to the anus as possible and the gut then cut into sections for examination. The first cut was made at the pyloric sphincter. The small intestine was cut into two sections. The anterior portion (the first 25%) being taken as the duodenum. The large intestine was separated into the caecum (including appendix), the colon and the rectum.

Initially examination for endoparasites was by dissection and the inspection of gut contents under a low-power microscope (x 16). Worms present were separated from the other gut contents with dissecting needles, counted and then placed in preservative for later identification. This method proved successful with mice, but with rats examination of the greater quantities of gut contents proved to be too time consuming and collection of cestodes very difficult. Because of this the remainder of the alimentary tract

sections were cut longitudinally and their contents washed into a large (180 mm diameter) sieve (0.25 mm x 0.25 mm mesh aperture). Any material adhering to the tissue was removed by pulling the section through between the thumb and fore-finger while washing. The residue was then washed into one or more glass petri dishes and examined under a low-powered microscope (x 16). Endoparasites present were counted and collected. Initially nematodes were stored in 70% alcohol and later in T.A.F. nematode fixative. All measurements necessary for identification were recorded from fresh material mounted in saline. Cestodes and trematodes were stored in 70% alcohol.

After the removal of the gut, the bladder, liver, heart, lungs and oesophagus (as far forward as the lower jaw) were removed and placed on a petri dish for dissection and inspection under the low-power microscope (x 16). The abdominal and thoracic cavities were then examined for any evidence of helminths and in most rats from North Canterbury (sample stations 14 (in part) and 15) the diaphragm was removed, pressed between two glass slides, and examined for Trichinella spiralis larvae.

The gall bladder was opened and the liver surface inspected for evidence of helminths. Where cysts were present these were removed intact and stored in 70% alcohol for later examination. Where nematode eggs occurred on the liver surface the tissue was teased opened using fine needles and forceps to check for adult worms. The bladder was opened and nematodes present were removed and fixed for later examination. Dissection of the heart and pulmonary arteries was carried out as described by Mackerras and Sanders (1955). The trachea were examined. The oesophagus was opened longitudinally and the mucosa and sub-mucosa examined under the low-power microscope (x 16). The nematodes present were removed by using fine dissecting needles to tease apart the tissue.

(ii) Ectoparasite Collection

Initially ectoparasite examinations were by a combination of brushing, combing and searching in the fur using a specially mounted low-power microscope. Examination

was always done in a clean white tray and the dislodged parasites were collected from this. This technique was not only laborious and time consuming, but was ineffective in detecting myobiid mites and lice embedded in the skin. The fur dissolving techniques were then investigated and that of Hilton (1970) was used for fourteen rats. Practical problems with the zinc sulphate flotation method occurred with heavily infested hosts. A proportion of the fleas and lice (increasing with infestation) were found in the sediment in the centrifuge tubes and the prolonged boiling in this method rendered lice nymphs and myobiid mites extremely soft and difficult to extract from the centrifuge tubes. As a consequence of these difficulties the remaining hosts were examined using a simplified form of the fur dissolving techniques of Buxton (1934) and Hopkins (1949). An analysis of the numbers examined by each method is given in Appendix A.

The host carcasses examined using the modified Buxton-Hopkins method were skinned and the pelt placed in a one litre beaker. Between 200 and 500 mls of 7% potassium hydroxide solution was then added according to the size of the pelt. Care was taken during skinning to ensure that the minimum of fat was left attached to the skin as saponification occasionally made parasite collection difficult in later stages of the process.

The pelts were then left for from 24 to 48 hours in the KOH solution, brought to the boil and allowed to boil vigorously for from 15 - 30 seconds. In most cases this was sufficient to ensure disintegration of the pelt. Where the skin either failed to break up or formed a gelatinous mass a further 200-300 mls of KOH solution were added. This mixture was stirred and allowed to stand for a further 24 hours before reheating. The dissolving of the skin and fur was then invariably achieved. This solution was left to cool and then poured through a small (80 mm diameter) sieve (0.18 x 0.18 mesh aperture). Any residue remaining in the beaker was washed out with water. The material in the sieve was washed with a stream of cold water until all the dark protein suspension had been removed. The residue was then washed into one or more petri dishes.

Fleas and lice present were counted and either prepared for mounting or preserved in 70% alcohol. The myobiid mites were then counted and a sample mounted in Hoyer's medium for later identification. Where tissue damage to the ears (as caused by Notoedres muris) was evident, these were removed and dissolved in KOH in a separate beaker. All other mites were collected and mounted in Hoyer's medium for later identification. Other arthropods recovered from the fur were stored in 70% alcohol and submitted to other students and staff for identification.

CHAPTER 3

RESULTS

A. CLASSIFICATION OF PARASITE SPECIES RECOVERED

No new species have been described and the source of the classification used in each group is given in parenthesis after each numbered heading.

(i) Fleas (Smit, 1965)

Class	Insecta
Order	Siphonaptera
Family	Pygiopsyllidae
	Pygiopsylla hoplia Jordon and Rothschild 1922
Family	Leptopsyllidae
	Leptopsylla segnis (Schonherr 1811)
Family	Ceratophyllidae
	Nosopsyllus fasciatus (Bosc 1800)
Family	Pulicidae
	Xenopsylla cheopis (Rothschild 1903)
	Xenopsylla vexabilis Jordon 1925

(ii) Lice (Johnson, 1964)

Class	Insecta
Order	Anoplura
Family	Hoplopleuridae
	Hoplopleura pacifica Ewing 1924
	Polyplax spinulosa (Burmeister 1839)
	Polyplax serrata (Burmeister 1839)*

(iii) Mites (Johnston, 1965)

Category A	
Class	Arachnida
Order	Acariformes
Sub-order	Acaridei
Family	Myocoptidae
	Myocoptes musculinus (Koch 1838)
Family	Sarcoptidae
	Notoedres muris Megnin 1877
Sub-order	Eleutherengona

Family Myobiidae

Myobia musculi (Schrank 1781)

Radfordia affinis (Poppe 1896)*

Radfordia ensifera (Poppe 1896)*

Category B

Class Arachnida

Order Parasitiformes

Sub-order Mesostigmata

Group Gamasina

Family Dermanyssidae

Dermanyssus gallinae (De Geer 1778)

Family Laelapidae

Sub-family Haemogamasinae

Eulaelaps stabularis (Koch 1836)

Haemogamassus pontiger (Berlese 1903)**

Sub-family Laelaptinae

Hypoaspis nidicorva Evans and Till 1966*

Hypoaspis sardoa (Berlese 1911)*

Hypoaspis miles (Berlese 1892)*

Hypoaspis sp. No. 1

Hypoaspis sp. No. 2

Hypoaspis sp. (nymph)

Androlaelaps casalis (Berlese 1887)*

Sub-family Macronyssinae

Hirstionyssus latiscutatus (de Meillon and Laviopierre 1944)*

Hirstionyssus sp.*

Hirstionyssus sp. (nymph)*

Myonyssus decumani Tiraboschi 1904*

Category C

Class Arachnida

Order Parasitiformes

Sub-order Metastigmata

Family Ixodidae

Ixodes sp.

Sub-order Mesostigmata

Group Gamasina

Family Ameroseiidae

Kleemania sp.

Family Blattisociidae s.l.

Sub-family Blattisociinae

Asca sp.

Proctolaelaps hypudaei (Oudamans 1902)

Family Macrochelidae

Macrocheles perglaber Filipponi and Pegazzano 1962 *

Macrocheles scutatus (Berlese)*

Family Parasitidae

Family Phytoseiidae

Family Rhodacaridae s.l.

Group Uropodina

Family Uropodidae

Order Acariformes

Sub-order Acaridei

Family Acaridae

Acarus sp.

Caloglyphus sp. **

——— sp.

Family Glycyphagidae

Glycyphagus destructor (Schrank 1781)

Sub-order Eutheregona

Family Cheyletidae

Sub-order Oribatei

Family Orabatidae

(iv) Roundworms (Yamaguti, 1961)

Class Nematoda

Order Trichuridea

Family Trichuridae

Sub-family Capillariinae

Capillaria hepatica (Bancroft 1893) *

Capillaria ? sp. *

Family Trichosomoididae

Trichosomoides crassicauda (Bellingham 1840) *

Order Spiruridea

Family Spiruridae

Sub-family Spirurinae

Mastophorus muris (Gmelin 1790) (= Protospirura muris Seurat 1914)

Order Strongylidae

Family Trichostrongylidae

Sub-family Viannaiinae

Nippostrongylus brasiliensis (Travassos 1914) *

Sub-family Heligmosominae

Heligmosomoides polygyrus (Dujardin 1845)
(= Nematospiroides dubius Baylis 1926) *

Order Oxyuridea

Family Oxyuridae

Sub-family Syphaciinae

Syphacia obvelata (Rudolphi 1802) *

Syphacia muris Yamaguti 1941 *

Family Heterakidae

Sub-family Heterakinae

Heterakis spumosa Schneider 1866 *

(v) Tapeworms (Yamaguti, 1959)

Class Cestoda

Sub-class Eucestoda

Order Cyclophyllidea

Family Taeniidae

Hydatigera taenaeformis (Batsch 1786)

(This parasite was recovered as a strobilocercus only)

Family Hymenolepididae

Hymenolepis diminuta (Rudolphi 1819)

Hymenolepis nana (Siebold 1852) *

(vi) Flukes (Yamaguti, 1958)

Class Trematoda

Order Digenea

Sub-order Prosotomata

Family Plagiorchiidae

Sub-family Plagiorchiinae

Plagiorchis muris Tanabe 1922 *

* Not previously recorded in New Zealand.

** Previously recorded in the New Zealand sub-region only from Macquarie Island.

Classification of other species recovered from rodent fur.

The number of rodents carrying each are given in parenthesis after each locality.

Class Arachnida

Order Phalangida: Cuvier Island (1)

Class	Insecta
Order	Hemiptera
Family	Aphidae : Cuvier Island (1), Christchurch (1), Dunedin (1).
Order	Collembola : Cuvier Island (3), North Canterbury (1), Christchurch (1).
Order	Hymenoptera
Family	Formicidae : Cuvier Island (Prolasius advena) (2), North Canterbury (1).
Order	Psocoptera : Christchurch (1)
Order	Coleoptera
Family	Curculionidae : Auckland (4), Christchurch (Siophilus oryzae) (4).
Family	Dermestidae : Christchurch (1)
Family	———— : Auckland (4), Cuvier Island (2), Red Mercury Island (1), Christchurch (3), Timaru (1), Dunedin (2).

B. FLEAS KNOWN TO OCCUR, OR LIKELY TO OCCUR, ON RODENTS IN NEW ZEALAND

Key to Adults: (after R.L.C. Pilgrim (unpublished)).

Hosts added in parenthesis.

1.	Comb present on pronotum at least * (Fig. 1 A)	2.
1'.	Comb absent from pronotum	8.
2.(1)	Comb present on gena as well as pronotum (Fig. 1 A)	3.
2'.	Comb absent from gena	5.
3.(2)	Genal comb horizontal **	4.
3'.	Genal comb vertical **	

Leptopsylla segnis (mouse and Rattus spp.)

4.(3) Frons prominently and evenly rounded, its radius of curvature centered about posterio-ventral corner of eye; first spine of genal comb more slender than second and about half the length of the latter; hind tibia with two stout setae between most distal pair of setae and distal end of tibia

Ctenocephalides canis (dog, occasionally rodents)

4'. Frons more flatly rounded; its radius of curvature below and behind the eye; first spine in genal comb about as stout as second and more than half the

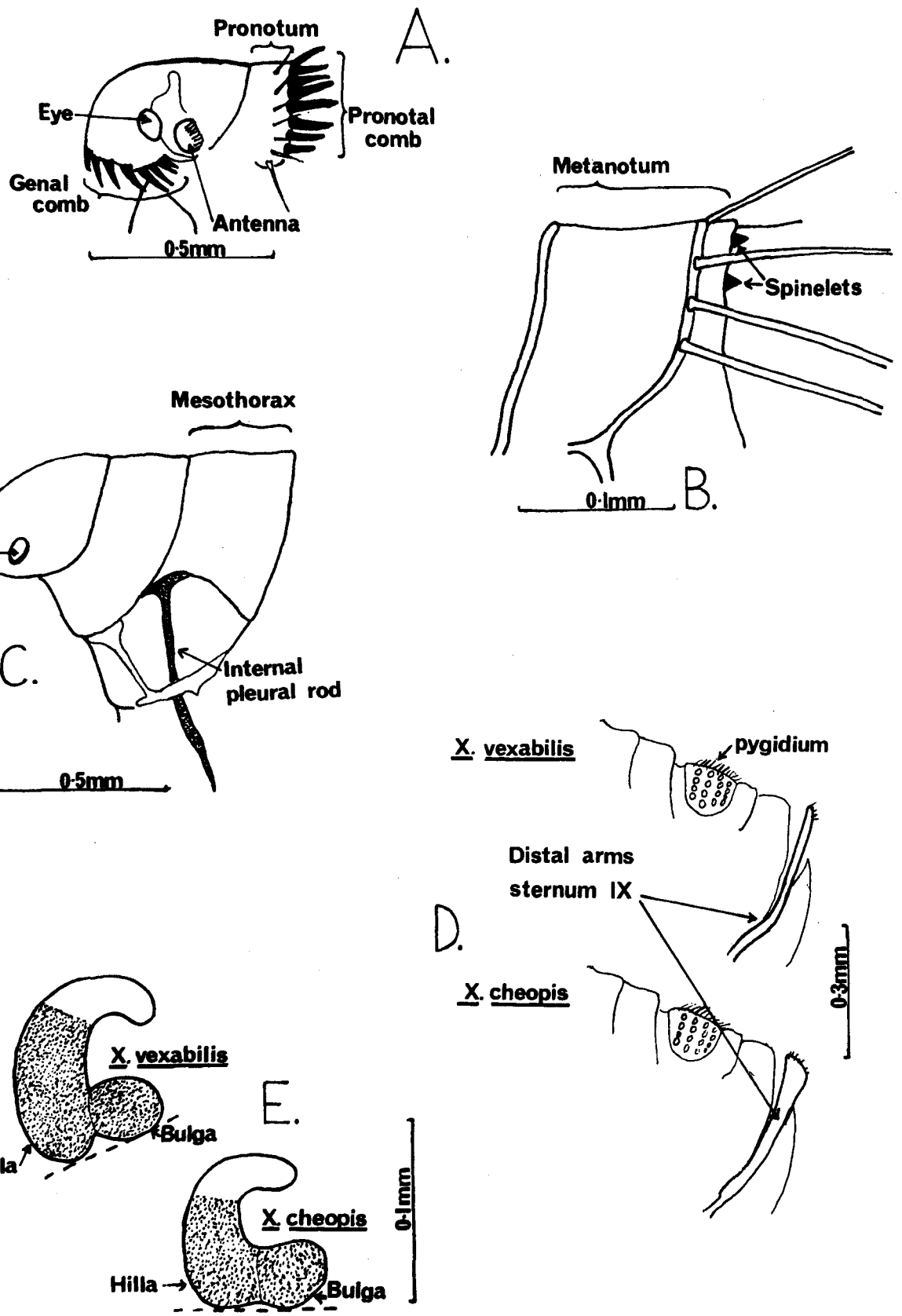

Pronotum
A.
Eye
Pronotal comb
Genal comb
Antenna
0·5mm
Metanotum
Spinelets
0·1mm
B.
Mesothorax
Eye
C.
Internal pleural rod
0·5mm
X. vexabilis
pygidium
Distal arms sternum IX
D.
X. cheopis
0·3mm
X. vexabilis
E.
Bulga
Hilla
X. cheopis
Hilla
Bulga
0·1mm

Figure 1. Glossary of characters used in key to rodent fleas.

length of the latter; hind tibia with only one stout setae between most distal pair of setae and distal end of tibia

Ctenocephalides felis felis (cat, occasionally rodents)

5.(2) Metanotum (and some abdominal tergites) bearing one or more spinelets (Fig. 1 B) 6.

5'. Metanotum without spinelets, pronotal comb of 16-18 spines, female with spermatheca having hilla shorter than bulga

Pygiopsylla hoplia (*Rattus* spp.)

6.(5) Pronotal comb of 26-34 spines

Ceratophyllus gallinae (fowl, occasionally rodents)

6'. Pronotal comb of no more than 24 spines 7.

7.(6') Longest apical bristle of segment 2 of hind tarsus longer than segment 3 of tarsus

Nosopsyllus londiniensis londiniensis (mouse and *Rattus* spp.)

7'. Longest apical bristle of segment 2 of hind tarsus shorter than segment 3 of tarsus

Nosopsyllus fasciatus (*Rattus* spp. and mouse)

8.(1') Mesothorax without an internal pleural rod

Pulex irritans (man, pig, occasionally rodents)

8'. Mesothorax with an internal pleural rod (Fig. 1 C) 9.

9.(8') Males 10.

9'. Females 11.

10.(9) Apex of distal arm of sternum IX broadened; not strongly, but uniformly sclerotised throughout its length (Fig. 1 D)

Xenopsylla cheppis (*Rattus* sp.)

10'. Apex of distal arm of sternum IX not broadened, sclerotised more strongly along its ventral margin which thus appears darker in profile (Fig. 1 D)

Xenopsylla vexabilis (*Rattus exulans*)

11.(9') Lower margin of spermatheca approximately level with only a slight indentation (Fig. 1 E)
Xenopsylla cheopis (*Rattus* spp.)

11'. Lower margin of spermatheca with distinct indentation and hilla projecting below level of the bulga (Fig. 1 E)
Xenopsylla vexabilis (*Rattus exulans*)

* Note, pronotal comb may comprise as few as two spines, the total count referring to the two sides combined.

** Note, orientation refers to comb as a whole, not to individual spines.

C. HOST-PARASITE INDEX

Order Rodentia
Family Muridae

Rattus exulans (Peale 1848) - Polynesian rat (Kiore)

Siphonaptera	*Nosopsyllus fasciatus*
	Pygiopsylla hoplia
	Xenopsylla vexabilis
Anoplura	*Hoplopleura pacifica*
Acarina	
(Category A)	*Radfordia ensifera*
(Category B)	*Dermanyssus gallinae*
	Eulaelaps stabularis
	Hypoaspis nidicorva
	Hypoaspis sardoa
	Hypoaspis miles
	Hypoaspis sp. No. 1
	Hirstionyssus sp. (nymph)
(Category C)	*Kleemania* sp.
	Asca sp.
	Macrocheles scutatus
	F. Parasitidae
	F. Rhodacaridae s.l.
	F. Acaridae
	F. Orabatidae
	Ixodes sp.
Nematoda	*Capillaria hepatica*
	Capillaria ? sp.

	Mastophorus muris
	Syphacia muris
Cestoda	Hymenolepis diminuta
Trematoda	Plagiorchis muris

Rattus rattus (Linnaeus 1769) - Ship rat, roof rat.

Siphonaptera	Leptopsylla segnis
	Nosopsyllus fasciatus
	Pygiopsylla hoplia
	Xenopsylla cheopis
Anoplura	Polyplax spinulosa
Acarina	
(Category A)	Radfordia ensifera
	Notoedres muris
(Category B)	Haemogamassus pontiger
	Hypoaspis sp. (nymph)
	Hirstionyssus latiscutatus
	Hirstionyssus sp.
	Hirstionyssus sp. (nymph)
(Category C)	Kleemania sp.
	F. Uropodidae
	Caloglyphus sp.
	F. Acaridae
	Glycyphagus destructor
	F. Cheyletidae
	F. Orabatidae
Nematoda	Capillaria hepatica
	Capillaria ? sp.
	Mastophorus muris
	Nippostrongylus brasiliensis
	Syphacia muris
	Heterakis spumosa
Cestoda	Hymenolepis diminuta
	Hymenolepis nana

Rattus norvegicus (Berkenhout 1767) - Brown rat.

Siphonaptera	Leptopsylla segnis
	Nosopsyllus fasciatus
	Pygiopsylla hoplia
Anoplura	Polyplax spinulosa
	Hoplopleura pacifica

Acarina	
(Category A)	Radfordia ensifera
	Notoedres muris
(Category B)	Hypoaspis nidicorva
	Hypoaspis sp. No. 2
	Androlaelaps casalis
	Hirstionyssus latiscutatus
(Category C)	Macrocheles perglaber
	F. Uropodidae
	F. Acaridae
	F. Cheyletidae
Nematoda	Capillaria ? sp.
	Mastophorus muris
	Nippostrongylus brasiliensis
	Syphacia muris
	Heterakis spumosa
	Trichosomoides crassicauda
Cestoda	Hydatigera taenaeformis (strobilocerci)
	Hymenolepis diminuta
	Hymenolepis nana

Mus musculus (Linnaeus 1758) - House mouse

Siphonaptera	Leptopsylla segnis
	Nosopsyllus fasciatus
Anoplura	Polyplax serrata
Acarina	
(Category A)	Myobia musculi
	Radfordia affinis
	Myocoptes musculinus
(Category B)	Eulaelaps stabularis
	Haemogamassus pontiger
	Hirstionyssus latiscutatus
	Myonyssus decumani
(Category C)	Proctolaelaps hypudaei
	Acarus sp.
	Caloglyphus sp.
	F. Acaridae
	F. Cheyletidae
	F. Orabatidae
Nematoda	Heligmosomoides polygyrus (= Nematospiroides dubius)

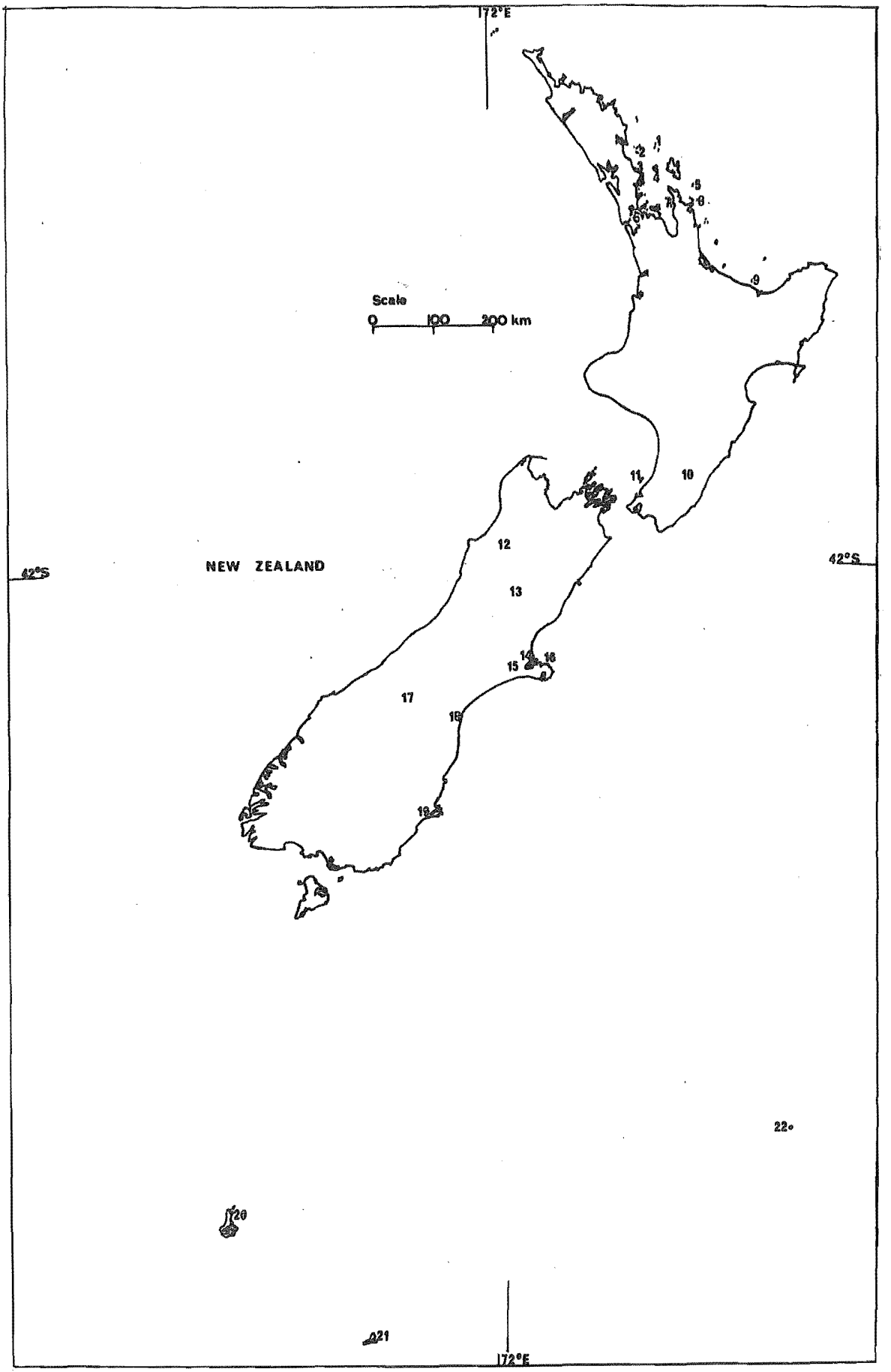

172°E
Scale
0 100 200 km
NEW ZEALAND
42°S
42°S
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
172°E

Figure 2. Location of collection stations listed in Table 1.

Syphacia obvelata

Cestoda Hydatigera taenaeformis (strobilocerci)

Hymenolepis diminuta

D. HOST DISTRIBUTION AND SAMPLE COMPOSITION

The distribution of host species obtained (Table 1) was largely a consequence of the availability of collectors thus numerous localities and habitats occupied by these hosts in New Zealand, were not sampled. This also resulted in discontinuous samples with time (Table 2), for each of the host species. The sex and age composition of the host samples (Table 3) were determined for analysis of the extent of parasite infections.

Of the 317 hosts examined for ectoparasites 157 were brushed or combed and the skin and fur then examined using a stereo microscope (x 6). Most of these (117) were mice (Appendix B) whose smaller surface area made such an examination quite feasible. The fur dissolving techniques utilised and the numbers examined by each are listed in Appendix B.

Three of the R. norvigicus and 41 of the M. musculus examined for ectoparasites were not utilised for endoparasite examination. These were rodents whose viscera had been damaged during collection. Most of the nestling mice obtained were discarded. The thoracic organs were not examined in 71 of the hosts (Appendix B). For several hosts this was because of collection damage and in the sixty mice, examined as the first stage of this survey, the thoracic organs were not included as potential sites for endoparasites. During the examination of the first three R. exulans received the presence of nematodes (Capillaria ? sp.) in sloughed-off mucosal tissue among the stomach contents led to the examination of the oesophagus and the detection of Capillaria ? sp. in the mucosa and sub-mucosa. In all hosts examined after this the oesophagus was examined.

E. FLEAS (SIPHONAPTERA)

The five species of fleas recovered have all been previously recorded from New Zealand and their known

Table 1 HOST SPECIES PRESENT AT EACH COLLECTION STATION

Collection Station Number (Refer Fig. 2)	Locality	*Rattus exulans*	*R. rattus*	*R. norvegicus*	*M. musculus*
1	Burgess I. (Moko Hinau Gp.)	x			
2	Hen and Chicken Is.*	x			
3	Goat I. (Leigh)		x		
4	Little Barrier I.	x			
5	Cuvier I.	x			
6	Auckland City		x		
7	Motukawao Gp.		x	x	
8	Red Mercury I.	x			
9	Whale I.			x	
10	Mt Bruce Reserve		x	x	
11	Kapiti I.	x		x	
12	Inangahua		x		
13	Lake Taylor		x		
14	Christchurch City		x	x	x
15	North Canterbury rural			x	x
16	Quail I.		x		x
17	McKenzie country			x	x
18	Timaru City		x		x
19	Dunedin City		x		
20	Auckland Is.				x
21	Campbell I.			x	
22	Antipodes Is.				x
	No. of Localities	6	10	8	7

* Via D.S.I.R. (Lower Hutt) where it had died in captivity.

Table 2 HOST SPECIES PRESENT AT EACH COLLECTING STATION

Month	Host species *R. exulans*	*R. rattus*	*R. norvegicus*	*M. musculus*
Jan	6			1
Feb		2	2	5
Mar		6	15	41
Apr	1	13	21	57
May		14	1	17
Jun	21	1	1	8
Jul		1	1	3
Aug	12		3	
Sep	3	14	12	
Oct		10	3	3
Nov	10	2*	*	1
Dec		4	1	

* Three pooled samples of ectoparasites from *R. rattus* and six from *R. norvegicus* obtained (each of 1-4 rats).

Table 3 COMPOSITION OF HOST SAMPLES

Host sp.	Total Collected	Total ♂	Total ♀	Adult ♂	Adult ♀	Juv-enile ♂	Juv-enile ♀
R. exulans	53	29	24	25	23	4	1
R. rattus	68	29	39	22	33	7	6
R. norvegicus	60	34	26	20	20	14	6
M. musculus	136	65	71	52	56	13	15
All hosts	317	157	160	119	132	38	28

distribution summarized by Smit (1965). The new records from this survey and localities confirmed are listed separately. As in Smit's (1965) paper the localities are listed from north to south.

(i) New Localities

Family PYGIOPSYLLIDAE

Pygiopsylla hoplia Jordan and Rothschild 1922

Motukawao Group

Motuwinukenuke I., 8.XI.1971, from Rattus norvegicus, 9 M. 10 F. 1?

Motukaramarama I., 9.XI.1971, from R. norvegicus, 4 M. 4 F.

Ngamotukaraka I., 6.XI.1971, from R. norvegicus, 11 M. 6 F. 1?

Motukahaua I., 9.XI.1971, from R. rattus, 5 M. 3 F. 1?

Red Mercury Island

.VIII.1971, from R. exulans, 2 F.

Whale Island

7.X.1971, from R. norvegicus, 2 M. 1 F.

Kapiti Island

.IX.1966, from R. exulans, 1 M.: .IX.1966, from R. norvegicus 3 M. 1 F. (including one flea recovered from a host's caecum)

North Canterbury

Heathcote Valley .III.1971, from R. norvegicus, 3 M .

Family LEPTOPSYLLIDAE

Leptopsylla segnis (Schonherr 1811)

Motukawao Group

Motukahaua I., 9.XI.1971, from R. rattus, 2 M. 1 F.

Mount Bruce Reserve

13.IX.1971, from R. rattus, 1 M.

Inangahua

29.X.1971, from R. rattus, 5 F.

North Canterbury

Harewood, .III.1971, from R. norvegicus, 2 M. 4 F.

Akaroa, 10.V.1970, from Mus musculus, 2 F.: 12.VII.1970 from M. musculus, 1 F .

Quail Island

24.V.1970, from M. musculus, 2 M. 3 F.: 13.IV.1971 from M. musculus, 2 F., 1 ? : .IV.1971, from R. rattus, 19 M. 50 F.

:15.V.1971, from R. rattus, 5 F.

Family CERATOPHYLLIDAE

Nosopsyllus fasciatus (Bosc 1800)

Burgess Island
24.VIII.1971, from R. exulans, 1 F .
Mount Bruce Reserve
30.VI.1971, from R. norvegicus, 1 F.: 27.IX.1971, from R. norvegicus, 1 F.: 27.IX.1971, from R. rattus, 1 F .
Inangahua
29.X.1971, from R. rattus, 1 F .
Quail Island
13.IV.1971, from R. rattus, 1 F.: 15.V.1971, from R. rattus, 1 M. 1 F .
Timaru
9.IV.1971, from R. rattus, 2 M 2 F .

Family PULICIDAE

Xenopsylla vexabilis Jordan 1925

Cuvier Island
.VII-VIII.1966, from R. exulans, 1 M .
Red Mercury Island
.VIII.1971, from R. exulans, 1 M .

(ii) Confirmed localities

Family LEPTOPSYLLIDAE

Leptopsylla segnis (Schonherr 1811)

Christchurch
Numerous records 1970 and 1971, from M. musculus : Numerous records 1971 from R. rattus.

Family CERATOPHYLLIDAE

Nosopsyllus fasciatus (Bosc 1800)

Auckland
.XII.1971, from R. rattus
Cuvier Island
.VII-VIII.1966, .VI and XI.1971, .I.1972, from R. exulans.
Christchurch
.III and IV.1970, from M. musculus : Numerous records 1971

from R. rattus and R. norvegicus.

Family PULICIDAE

Xenopsylla cheopis (Rothschild 1903)

Auckland

.XII.1971, from R. rattus.

Xenopsylla vexabilis Jordan 1925

Little Barrier Island

.XI.1971, from R. exulans.

(iii) Distribution and incidence

The geographic distributions of the flea species and the hosts from which they were recovered are shown in Table 4. The flea distributions presented are partially the product of the limitations outlined for the host distributions i.e. the availability of collectors.

The distribution and the incidence of fleas (Table 5) can be considered as minimum values only. The results presented are a summary of all fleas recovered without consideration of habitat, seasonal or trapping-method factors.

Significant variation from a 1:1 sex ratio occurs in only one flea species, Leptopsylla segnis (prob. < 0.001) but the sample sizes of the Xenopsylla species were too small to allow comparison. Of the 142 L. segnis collected, the sex of three could not be determined, 39 were males and 100 were females.

The numbers of males and females infested with fleas were not significantly different, even at the 0.25 confidence level, for any of the host species.

The presence of the various flea species at different times of the year was examined for each of the four host species (Tables 6, 7, 8 and 9). As a qualification of the validity of recording the absence of a flea species in any given month, the number of hosts examined in that month have been included in each table.

The predominant fleas in both the North and South Island localities, regardless of host species, were L. segnis and N. fasciatus (Tables 11, 12 and 13). The other two flea species present on the North and South Islands had an

Table 4 GEOGRAPHIC DISTRIBUTION OF FLEAS

Collection Station Number (Refer Fig. 2)	Leptopsylla segnis	Nosopsyllus fasciatus	Pygiopsylla hoplia	Xenopsylla cheopis	Xenopsylla vexabilis
1		e			
2					
3					
4					e
5		e			e
6		r		r	
7	r		rn		
8			e		e
9			n		
10	r	rn			
11			en		
12	r	r			
13					
14	rnm	rnm			
15	nm		n		
16	rm	r			
17					
18		r			
19					
20					
21					
22					
23					

Key: e = Rattus exulans r = Rattus rattus
n = Rattus norvegicus m = Mus musculus

Table 5 THE INCIDENCE OF FLEAS ON EACH HOST SPECIES

Host species	Number examined	Number infested	Percentage infested	Mean nos. per host	Mean nos. per infected host	Range in numbers
Rattus exulans	53	25	47	3.1	5.0	1 - 12
Rattus rattus	68	27	40	2.0	4.4	1 - 35
Rattus norvegicus	60	13	21	0.5	1.6	1 - 5
Mus musculus	136	33	24	0.5	2.0	1 - 5

SEASONAL PRESENCE OF FLEAS

Table 6 RATTUS RATTUS + = Present

Month	J	F	M	A	M	J	J	A	S	O	N	D
No. hosts examined	0	2	6	13	14	1	1	0	14	10	2*	4
Fleas present	-	0	+	+	+	+	+	-	+	+	+	+
Leptopsylla segnis	-	0	+	+	+	+	+	-	+	+	+	0
Nosopsyllus fasciatus	-	0	+	+	+	0	+	-	+	+	0	+
Pygiopsylla hoplia	-	0	0	0	0	0	0	-	0	0	+	0
Xenopsylla cheopis	-	0	0	0	0	0	0	-	0	0	0	+

Table 7 RATTUS NORVEGICUS + = Present

Month	J	F	M	A	M	J	J	A	S	O	N	D
No. hosts examined	0	2	15	21	1	1	1	3	12	3	*	1
Fleas present	-	0	+	+	+	+	0	+	+	+	+	0
Leptopsylla segnis	-	0	+	0	0	0	0	0	0	0	0	0
Nosopsyllus fasciatus	-	0	+	+	0	+	0	0	+	0	0	0
Pygiopsylla hoplia	-	0	0	0	+	0	0	+	+	+	+	0

SEASONAL PRESENCE OF FLEAS (Cont'd)

Table 8 RATTUS EXULANS + = Present

Month	J	F	M	A	M	J	J	A	S	O	N	D
No. hosts examined	6	0	0	1	0	21	*	*12	3	0	10	0
Fleas present	+	–	–	0	–	+	+	+	+	–	+	–
Nosopsyllus fasciatus	+	–	–	0	–	+	+	0	0	–	+	–
Pygiopsylla hoplia	0	–	–	0	–	0	0	+	+	–	0	–
Xenopsylla vexabilis	0	–	–	0	–	0	+	+	0	–	+	–

Table 9 MUS MUSCULUS + = Present

Month	J	F	M	A	M	J	J	A	S	O	N	D
No. hosts examined	1	5	58	39	17	8	3	0	0	3	1	0
Fleas present	0	0	+	+	+	0	+	–	–	0	0	–
Leptopsylla segnis	0	0	+	+	+	0	+	–	–	0	0	–
Nosopsyllus fasciatus	0	0	+	+	0	0	0	–	–	0	0	–

* Pooled ectoparasite collections received.

apparently limited distribution. Xenopsylla cheopis was recovered only from Auckland city (Table 11) and Pygiopsylla hoplia from Heathcote (Table 12). P. hoplia occurred on several off-shore islands as did the two more prevalent species, particularly N. fasciatus. The remaining species, X. vexabilis was only recovered from Little Barrier, Cuvier and Red Mercury Islands (Table 10).

Although fleas were found to settle out in the precipitate when using Hilton's (1970) technique no significant difference was noted for fleas in the efficiency of either of the two main ectoparasite collection methods. Thirty-four fleas were obtained from a sample of six rats brushed and combed thoroughly before subjection to the fur dissolving technique. A further six were recovered by the latter procedure. The consideration of other factors such as host species, flea species, seasonal and habitat differences produced data unsuitable for statistical comparison as the samples had to be subdivided in such a way as to make them too small for use.

N. fasciatus was the only parasite recovered from nest material. It occurred in two R. norvegicus nests from near the Christchurch estuary and in a R. exulans nest from Cuvier Island. No parasites were collected from R. rattus nests obtained from Christchurch grain stores.

F. LICE (ANOPLURA)

All of the host species were infested with lice (Table 14). Two cosmopolitan species, Polyplax spinulosa and P. serrata, and one Malaysian-Pacific species, Hoplopleura pacifica, were collected.

(i) Geographic distribution and incidence

Polyplax spinulosa was the only louse recovered from R. rattus. This louse was present in all samples of R. rattus except those from Auckland (Table 15). No seasonal variation in louse infestation in monthly analysis was apparent. No quantitative comparison was attempted because of the varying efficiencies of the range of ectoparasite collection methods used. In the examination of both R. rattus and R. norvegicus

Table 10 FLEA INFESTATION WITH LOCALITY - *RATTUS EXULANS*

Locality	Rats examined	Rats infested	Nos. of each flea species: *Nosopsyllus fasciatus*	*Pygiopsylla hoplia*	*Xenopsylla vexabilis*	Flea indicies: per infected host	per host
Burgess I.	7	1	1	0	0	1.00	0.14
Hen & Chicken Gp.	1	0	0	0	0	0	0
Little Barrier I.	4	1	0	0	1	1.00	0.25
Cuvier I. *	33	23	156	0	0	5.69	4.73
Red Mercury I.	5	2	0	2	1	1.50	0.60
Kapiti I.	3	1	0	1	0	1.00	0.33
All localities	53	28	157	3	2	5.04	3.06

* A pooled ectoparasite collection from 39 rats obtained in July/August 1967 for food analysis work was also examined and 18 *N. fasciatus* and one *X. vexabilis* recovered.

Table 11 FLEA INFESTATION WITH LOCALITY - *RATTUS RATTUS*

Locality	Rats examined	Rats infested	Nos. of each flea species *Leptopsylla segnis*	*Nosopsyllus fasciatus*	*Pygiopsylla hoplia*	*Xenopsylla cheopis*	Flea indicies per infected host	per host
Auckland City	5	5	0	18	0	7	1.40	1.40
Motukawao Gp.	*	0	0	0	9	0		
Mt Bruce	7	2	1	1	0	0	1.00	0.29
Inangahua	7	3	5	1	0	0	2.00	0.86
Lake Taylor	1	0	0	0	0	0	0	0
Christchurch								
(commercial)	24	7	1	6	0	0	1.00	0.29
(suburban)	5	4	9	2	0	0	2.75	2.20
Quail I.	5	5	74	3	0	0	15.00	15.00
Timaru City	9	4	0	4	0	0	1.00	0.44
Dunedin City	3	0	0	0	0	0	0	0
All localities	71+	33+	93	35	9	7	4.36	2.03

* Three pooled ectoparasite samples of from one to four hosts each were obtained.

Table 12 FLEA INFESTATION WITH LOCALITY - *RATTUS NORVEGICUS*

Locality	Rats examined	Rats infested	Nos. of each flea species			Flea indicies per	
			Leptopsylla segnis	*Nosopsyllus fasciatus*	*Pygiopsylla hoplia*	infected host	per host
Motukawao Gp.	*	-	0	0	46	-	-
Whale I.	3	2	0	0	3	1.50	1.00
Mt Bruce	10	2	0	2	0	1.00	0.20
Kapiti I.	7	2	0	0	4	2.00	0.29
North Canterbury	12	2	8	0	0	4.00	0.66
Christchurch	22	5	0	11	3	2.80	0.64
McKenzie Country	3	0	0	0	0	0	0
Campbell I.	3	0	0	0	0	0	0
All localities	60	13	8	13	56	1.63	0.52

* Six pooled ectoparasite samples of from one to four hosts each.

Table 13 FLEA INFESTATION WITH LOCALITY - *MUS MUSCULUS*

Locality	Mice examined	Mice infested	Nos. of each flea species *Leptopsylla segnis*	Nos. of each flea species *Nosopsyllus fasciatus*	Flea indicies per infected host	Flea indicies per host
North Canterbury	28	2	3	0	1.50	0.11
Christchurch (commercial)	33	20	16	22	1.90	1.15
(suburban)	58	9	15	0	1.67	0.26
Laboratory stock (Christchurch)	3	0	0	0	0	0
Quail I.	3	2	8	0	4.00	2.67
McKenzie Country	1	0	0	0	0	0
Timaru	4	0	0	0	0	0
Antipodes I.	3	0	0	0	0	0
Auckland Is	3	0	0	0	0	0
All localities	136	33	42	22	2.00	0.49

the mean number of lice obtained per host was over 400% greater in those examined by the modified Buxton/Hopkins method (Tables 16 and 17) than the other methods. The variations in the range of numbers of lice recovered per host also differ by a comparable figure.

Table 14 LICE INFESTATION

Host species	No. hosts examined	No. hosts infested P. spinulosa	P. serrata	H. pacifica
R. exulans	53	1	0	53
R. rattus	68	44	0	0
R. norvegicus	60	31	0	2
M. musculus	136	0	1	0

All specimens of R. exulans examined were infested with lice. The size of hosts ranged from a 19 gram juvenile upward. The most heavily infested host was a 35 gram male which had been collected live from the Hen and Chicken Islands and had died in captivity at Lower Hutt. The total number of lice collected from this animal was 4004 and these consisted of both P. spinulosa and H. pacifica. No relationship between host body-weight and either adults, nymphs or total lice numbers was apparent and 178 lice were recorded from a juvenile R. exulans of only 26 grams. All of the lice other than on the 35 gram host mentioned above were H. pacifica.

As with R. exulans, lice were present over virtually the whole range of weight classes of R. rattus (Fig. 3). The smallest infested rat weighed 20 grams and all smaller rats examined were hairless nestlings. Two species of lice were recovered from R. norvegicus but H. pacifica occurred only on two rats collected on Kapiti Island. Polyplax spinulosa was present at all other localities except the McKenzie Country (Table 18). Lice were detected on R. norvegicus in each month of the year except July and December and only one host was examined in each of these

Table 15 LICE INFESTATION - RATTUS RATTUS

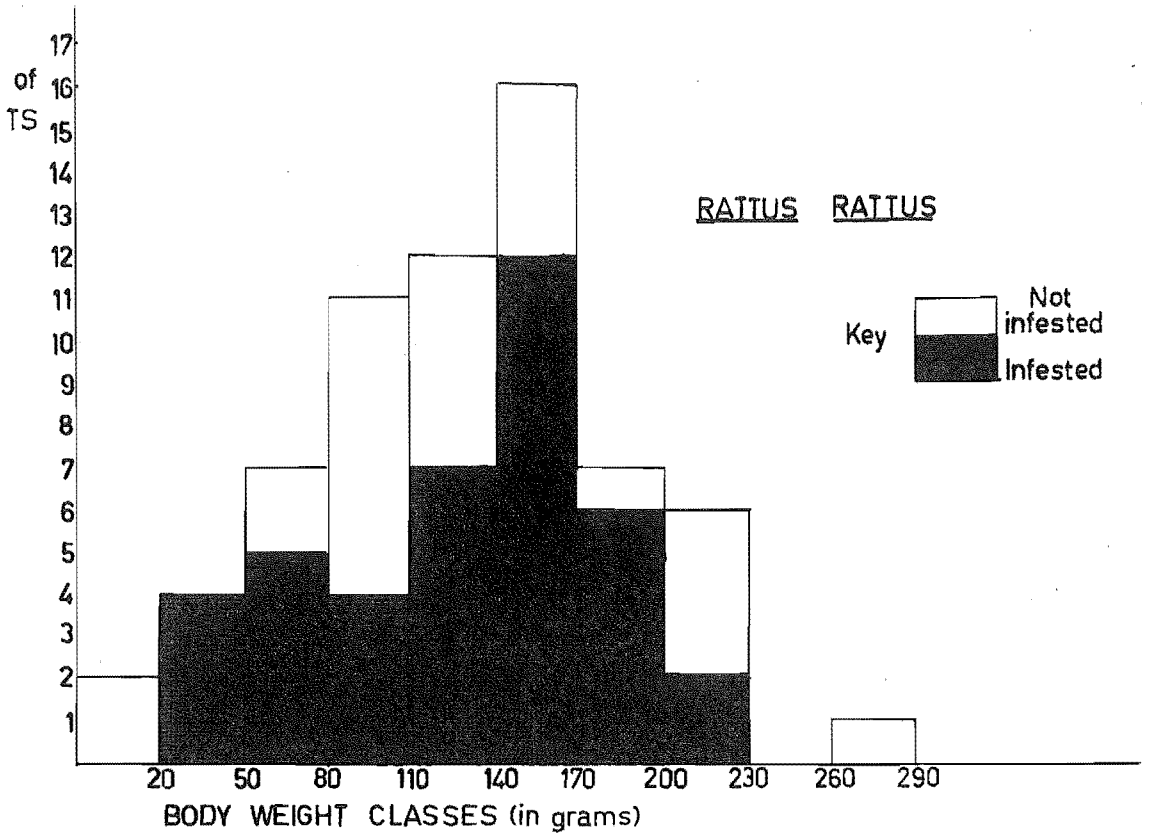
Locality	Rats examined	Rats infested	Mean Nos. lice/host *	Infested host body-weight range (in grams)
Goat I.	2	2	6.0	137-156
Auckland	5	0	0	-
Mt Bruce	7	7	9.0	105-172
Inangahua	7	5	28.5	116-204
Lake Taylor	1	1	8.0	110
Christchurch				
(Suburban)	5	1	5.0	68
(Commercial)	24	14	30.7	20-220
Quail I.	5	4	4.0	76-197
Timaru	9	7	16.3	84-184
Dunedin	3	2	2.5	158-194
All localities	68	43	19.2	20-220

* Raw data - no allowance made for louse collection method.

Table 16 LICE COLLECTION METHODS

	Collection Method	Number examined	Number infested	% infested	Mean No. lice/infested host	Range in nos./infested host
R. exulans	Buxton/Hopkins	53	53	100	182.4 (107.3)	3-4004 (3-491)
R. rattus	Brushed etc.	18	10	56	5.9	1-18
	Hiltons	9	4	44	6.0	2-15
	Buxton/Hopkins	41	29	71	25.0	1-148
	Total	68	43	63	18.8	
R. norvegicus	Brushed etc.	22	13	59	6.5	1-47
	Hiltons	5	2	40	6.0	2-12
	Buxton/Hopkins	33	17	52	28.9	1-169
	Total	60	32	53	18.3	
M. musculus	Brushed etc.	117	1	0.9	3.0	3
	Buxton/Hopkins	19	0	0	0	0
	Total	136	1	0.7	3.0	3

Note - The values in parenthesis are the mean and range if a single abnormally heavily infested host is not considered.


of
TS
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
RATTUS RATTUS
Key
Not infested
Infested
20
50
80
110
140
170
200
230
260
290
BODY WEIGHT CLASSES (in grams)

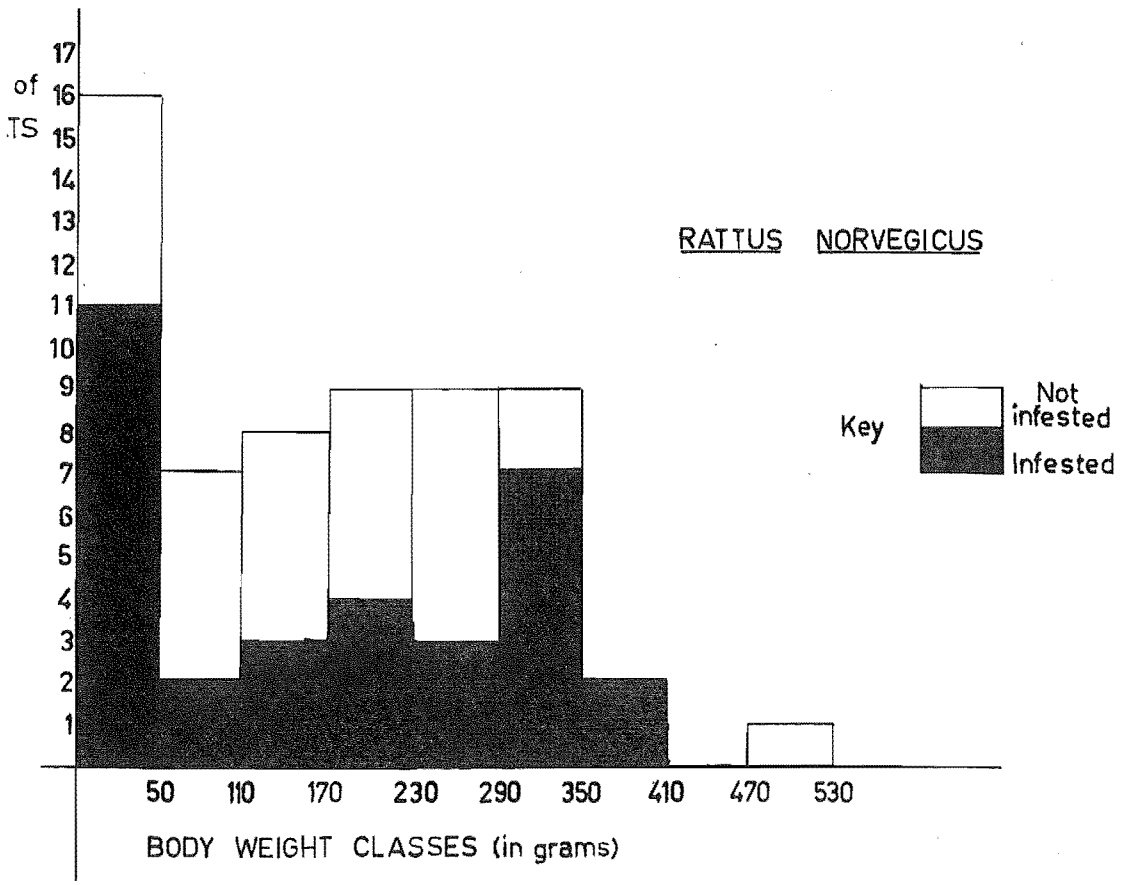

of
TS
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
RATTUS NORVEGICUS
Key
Not infested
Infested
50
110
170
230
290
350
410
470
530
BODY WEIGHT CLASSES (in grams)

Figure 3 Distribution of lice with host body-weights.

months.

Lice were collected over a wide range of host weight classes (Fig. 3) and the two smallest R. norvegicus obtained, both 21 grams, were infested. As with the monthly incidence of lice on hosts, comparisons of quantitative data from the various localities are restricted by the examination methods used.

(ii) Distribution of lice on Rattus exulans

Using the modified Buxton/Hopkins fur-dissolving technique, the distribution of adult lice and nymphs (Hoplopleura pacifica) on Rattus exulans were examined (Table 19).

The trend shown in all three samples was for a concentration of both adults and nymphs on the back (Fig. 4) with a fairly even distribution of nymphs over the rest of the body. Adult lice were fewer in the crutch region and numerous on the belly and flanks.

Polyplax serrata was recovered only once, from a mouse caught on Quail Island.

Examination of adult and nymphal lice, of all stages, on R. exulans showed that no significant differences from a 1:1 adult to nymph ratio occurred with either the month of host capture or the sex of the host. In the heavier host-weight classes this 1:1 ratio also occurred, but those rats of less than 80 grams had significantly more nymphs (562:375) at the 0.05 confidence level.* In only two of these 13 hosts did more adults occur. The total numbers of lice per host were also significantly smaller for hosts of less than 80 grams and for female hosts at the 0.05 confidence level.

To compare the ectoparasite collection methods several hosts (R. rattus) were brushed and combed prior to subjection to the KOH fur-dissolving technique and the numbers of lice and myobiid mites obtained by each method recorded (Table 17).

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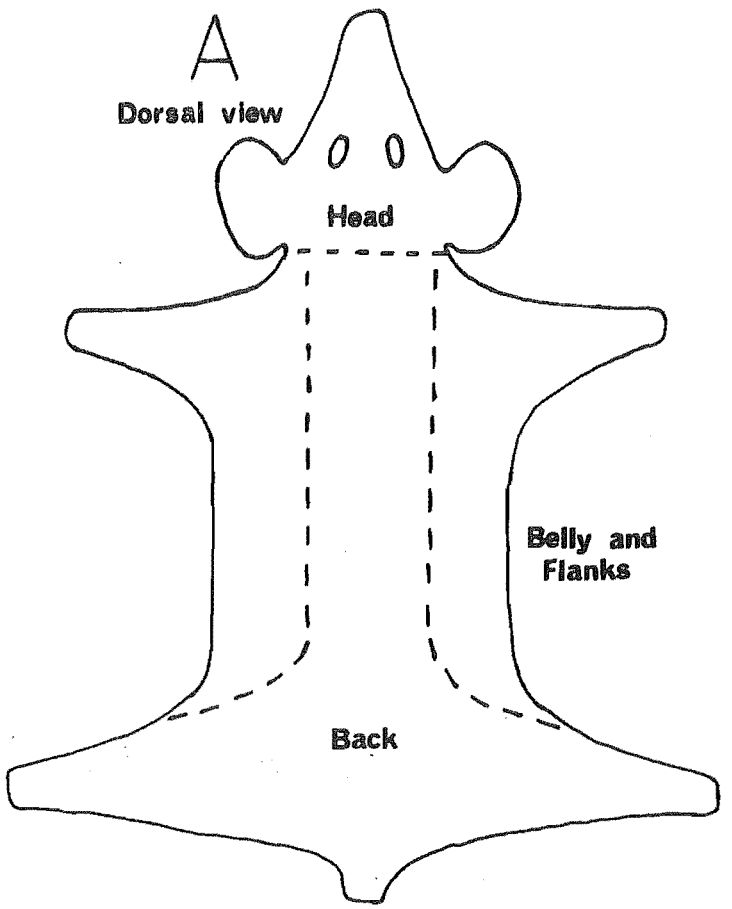
* This ratio and all subsequent computations did not include the host with 4004 lice.


A
Dorsal view
Head
Belly and
Flanks
Back

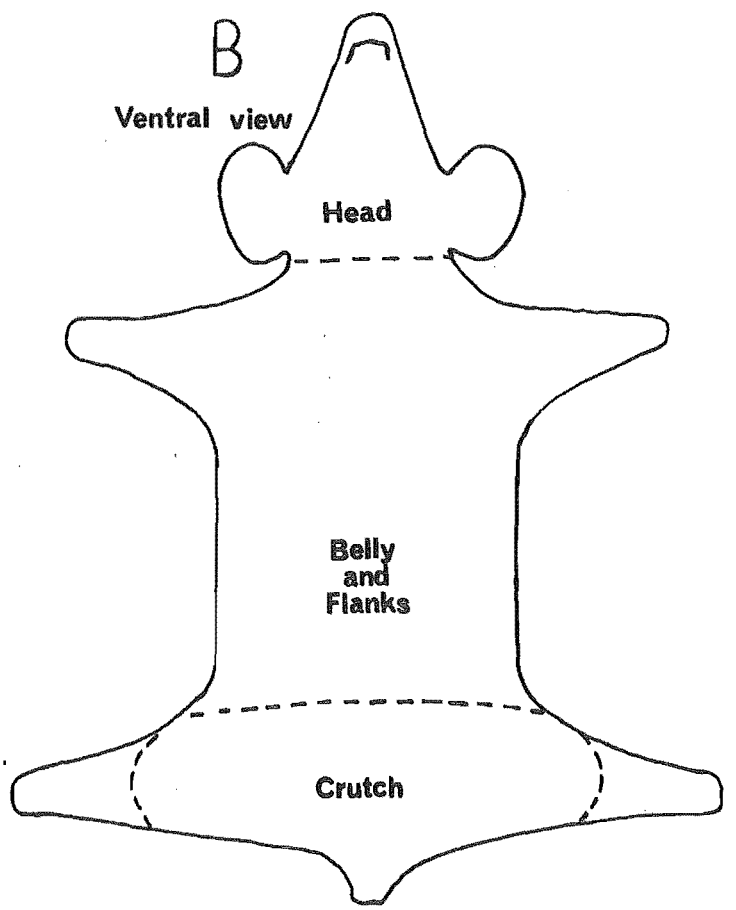

B
Ventral view
Head
Belly
and
Flanks
Crutch

Figure 4 Host regions (*Rattus exulans*) sampled for louse distribution.

Table 17 COMPARISON OF ECTOPARASITE COLLECTION METHODS ON *RATTUS RATTUS*

Host code number	Lice obtained: Brushing etc. Adults	Brushing etc. Nymphs	Total Adults	Total Nymphs	*Radfordia ensifera* obtained: Brushing etc.	Total
CNM1	17	6	80	16	93	411
CNM2	29	29	85	63	8	54
TW4	4	1	17	21	0	6
TW5	1	4	7	13	0	2
TW6	0	0	2	0	0	0

G. MITES (ACARINA)

The mites recovered have been classified into three groups. Category A were all obligatory parasites which, through modification of their limbs, were able to remain attached to their host's fur or in the host's skin throughout their life cycle. Category B included those mites reported in the literature as parasitic but possessing no limb modifications as above. These were all presumably able to move more readily to and from their host and were predominantly facultative parasites. Category C were the remaining mites collected with rodents. Many of these have been commonly reported in association with rodents and consisted of a range of the mites of stored products, nests, and so on.

Distribution and Incidence

(i) Category A

Five category A mite species were collected consisting of three Myobiidae, one Listropharidae and one Sarcoptidae. Three species were recovered exclusively from *Mus musculus*. These were *Myobia musculi*, *Radfordia affinis*

Table 18 LICE INFESTATION WITH LOCALITY - RATTUS NORVEGICUS

Locality	Rats examined	Rats infested	Mean Nos. lice/host *	Infested host body-weight range (in grams)
Motukawoa Gp.**	6+	5+	-	-
Whale I.	3	3	104	124-275
Mt Bruce	10	6	10.1	214-371
Kapiti I.	7	2	5.5	58-330
Christchurch	22	16	6.9	21-364
North Canterbury rural	12	6	16.3	201-334
McKenzie Country	3	0	-	-
Campbell I.	3	1	2.0	125

* Raw data - no allowance made for louse collection method.

** 6 pooled ectoparasite samples of 1-4 hosts each examined and lice detected in 5.

Table 19 DISTRIBUTION OF THE LOUSE HOPLOPLEURA PACIFICA ON RATTUS EXULANS

Body region	Cuvier I. June (7 hosts) Adults	Nymphs	Total	Burgess I. August (3 hosts) Adults	Nymphs	Total	Cuvier I. November (1 host) Adults	Nymphs	Total	Total for all hosts Adults	Nymphs	Total	Ratio 508:552 Chi^2 (from raw data)	Ratio 1:1 Chi^2
Crutch	5%	22%	14%	8%	4%	6%	6%	13%	10%	5%	17%	11%	<0.005	<0.005
Belly and Flanks	28%	18%	23%	27%	4%	13%	26%	20%	22%	28%	14%	21%	<0.005	<0.005
Back	48%	50%	49%	48%	66%	58%	67%	64%	66%	48%	54%	51%	>0.100	>0.025
Head	19%	10%	14%	17%	26%	23%	1%	3%	2%	19%	15%	17%	>0.050	>0.100
Total numbers	405	409	814	103	143	246	120	143	263	508	552	1060	-	>0.100

and Myocoptes musculinus. Radfordia ensifera was collected from all three species of Rattus (Tables 20, 21 and 22) and Notoredres muris from both R. rattus and R. norvegicus.

The geographic distribution of the five Category A mite species is given below with localities listed from north to south.

O. Acariformes

S.O. Acaridei

Family Myocoptidae

Myocoptes musculinus

Christchurch 6.X.1971, from Mus musculus.

Auckland Island (Ranui Cove) .I-II.1966, from Mus musculus.

Family Sarcoptidae

Notoedres muris

Goat Island (Leigh) 7.IX.1971, from Rattus rattus,

Inangahua 29.X.1971, from R. rattus.

Christchurch .VI and VII.1971, from R. rattus; 5.III.1971, from R. norvegicus.

Timaru 9.IV.1971, from R. rattus.

McKenzie Country 23.III.1972, from R. norvegicus.

S.O. Eleutherengona

Family Myobiidae

Myobia musculi

North Canterbury .III.1971, from M. musculus,

Christchurch .III, IV, V, VI, X and XI.1971, from M. musculus.

Quail Island .IV and V.1971, from M. musculus.

Timaru 9.IV.1971 from M. musculus.

McKenzie Country 23.III.1972, from M. musculus.

Antipodes Island 3-4.II.1969, from M. musculus.

Auckland Island (Ranui Cove) .I and II.1966 from M. musculus.

Radfordia affinis

Christchurch .VII.1970; .III and IV.1971, from M. musculus.

Akaroa .VII.1970, from M. musculus.

Auckland Island (Ranui Cove) .I and II.1966 from M. musculus.

Radfordia ensifera

This parasite occurred on every R. exulans collected and at least once from every sample of R. rattus and R. norvegicus collected. (Refer to Fig. 2 and Table 1 for distribution). It was also present in the pooled ectoparasite collection from Motuwinukenuke (Motukawao Group) off R. norvegicus.

Table 20 INFESTATION WITH *RADFORDIA ENSIFERA*

Host species	Number examined	Number infested	Mean no. per infected host	Range in nos. per host	Range in host body weights (in grams)
R. exulans	53	53	57.1	4-233	19.0-164
R. rattus	68	35	50.5	1-535	21.2-515
R. norvegicus	60	27	111.6	1-640	32.5-210

Table 21 *RADFORDIA ENSIFERA* INCIDENCE WITH COLLECTION METHOD (*R. RATTUS*)

Method	Number examined	Number infested	Total mites	Mean no. per infested host
Brushed etc.	18	2	51	25.5
Hilton's	9	1	2	2.0
Buxton/Hopkins	41	32	1915	59.8

Table 22 *RADFORDIA ENSIFERA* INCIDENCE WITH COLLECTION METHOD (*R. NORVEGICUS*)

Method	Number examined	Number infested	Total mites	Mean no. per infested host
Brushed etc.	22	2	2	1.0
Hilton's	5	0	0	0
Buxton/Hopkins	33	25	2922	116.9

Myocoptes musculinus occurred only on the mice from Auckland Islands and three mice from the University Zoology Department laboratory stock. Skin damage was evident on the laboratory mice probably the result of excessive scratching and the heavily infested animals examined were very lethargic.

Notoedres muris was detected on R. norvegicus twice from Christchurch and once from the McKenzie Country. On R. rattus it was detected five times; from Goat Island, Inangahua, Christchurch (twice) and Timaru. The lesions resulting from infestations of N. muris were obvious on gross examination of the hosts and only the ears were found to be infested. Over 100 mites were present in each infestation.

The distributions of Myobia musculi and Radfordia affinis recovered are limited to that of their particular host, Mus musculus. Myobia musculi was the more prevalent occurring in 17 of the 19 mice examined by the modified Buxton/Hopkins method and on seven of those examined by brushing etc. This mite occurred on mice from Christchurch, rural North Canterbury, Quail Island, Timaru, the McKenzie Country, Auckland Islands and Antipodes Island.

R. affinis occurred on five mice examined by the fur dissolving technique and three mice examined by brushing etc. It was recorded from Christchurch, Akaroa and the Auckland Islands. In the latter case R. affinis was recovered from the same hosts as Myobia musculi.

(ii) Category B

A range of Category B parasitic mites and some of uncertain status commonly found in association with rodents, were recovered. These are listed below and in each case the localities are listed from north to south.

O. Parasitiformes

S.O. Mesostigmata

Gamasina

F. Dermanyssidae

Dermanyssus gallinae

Cuvier Island 22.XI.1971, in container of Rattus exulans (in alcohol).

F. Laelaptidae

S.F. Haemogamasinae

Eulaelaps stabularis

Cuvier Island 22 and 24.VI.1971, from R. exulans.

Christchurch 20.IV.1970, from Mus musculus.

Haemogamassus pontiger

Christchurch -.IV.1970, from M. musculus.

Timaru 9.IV.1971, from R. rattus.

Dunedin 20.X.1971, from R. rattus.

S.F. Laelaptinae

Hypoaspis nidicorva

Burgess Island 24.VIII.1971, in container of R. exulans (in alcohol).

Cuvier Island -.VIII-IX.1967, from R. exulans; 23.VI.1971, from R. exulans; 22.XI.1971, from R. exulans.

Christchurch 23.IV.1971, from R. norvegicus.

Hypoaspis sardoa

Cuvier Island -.VIII-IX.1967, from R. exulans.

Hypoaspis miles

Cuvier Island 23.VI.1971, from R. exulans.

Hypoaspis sp. No. 1

Burgess Island 24.VIII.1971, from R. exulans.

Hypoaspis sp. No. 2

Whale Island 5.IX.1971, from R. norvegicus.

Hypoaspis sp. (nymph)

Christchurch 24.V.1971, from R. rattus.

Androlaelaps casalis

Christchurch 8.III.1971, from R. norvegicus.

S.F. Macronyssinae

Hirstionyssus latiscutatus

Auckland -.XII.1971, from R. rattus.

Christchurch -.III.1970, from M. musculus nest; 12.IV.1970, and 5.X.1971, from M. musculus; 24.III.1971, and 10.IX.1971, from R. rattus; 23.IV.1971, from R. norvegicus.

Dunedin 20.X.1971, from R. rattus.

Hirstionyssus sp. (nymph)

Cuvier Island 23.VI.1971, from R. exulans.

Timaru 9.IV.1971, from R. rattus.

S.F. Myonyssinae

Myonyssus decumani

Christchurch 1971 from M. musculus.

Akaroa 12.VII.1970, from M. musculus.

(iii) Category C

The range of mites in this category covered most localities and habitats occupied by their rodent "hosts" and they represent part of the Acarine fauna of these habitats.

O. Parasitiformes

S.O. Mesostigmata

Gamasina

Family Ameroseiidae

Kleemania sp.

Burgess Island .VIII.1971, from Rattus exulans.

Timaru .IV.1971, from Rattus rattus.

Family Blattisociidae s.l.

Sub-family Blattisociinae

Asca sp.

Cuvier Island .VI.1971 from Rattus exulans.

Proctolaelaps hypudaei

Christchurch .IV.1970, from Mus musculus.

Family Macrochelidae

Macrocheles perglaber

Mt Cook (Hermitage) .II.1972, from Rattus norvegicus.

Macrocheles scutatus

Cuvier Island .VI.1971, from container of Rattus exulans. (in alcohol)

Family Parasitidae

Little Barrier Island .XI.1971, from container of Rattus exulans (in alcohol).

Family Phytoseiidae

Mt Bruce .II.1971, from Rattus rattus.

Family Rhodacaridae s.l.

Cuvier Island .VII-VIII.1967, from container of Rattus exulans (in alcohol).

Uropodina

Family Uropodidae

Auckland .XII.1971, from Rattus rattus.

Kapiti Island .IX.1967 from Rattus norvegicus.

North Canterbury .III.1971 from intestine of Rattus norvegicus.

Christchurch .III.1971, from Rattus norvegicus.

O. Acariformes

S.O. Acaridei

Family Acaridae

Acarus sp.

Christchurch .III, IV.1970, from Mus musculus.

Caloglyphus sp.

Christchurch .IV.1971, from Mus musculus.

Timaru .IV.1971, from Rattus rattus.

——— sp.

Burgess Island .VIII.1971, from Rattus exulans.

Cuvier Island .VI.1971, from Rattus exulans.

Red Mercury Island .VIII.1971, from container Rattus exulans (in alcohol).

Kapiti Island .IX.1966, from Rattus exulans.

Christchurch .V.1971, from Rattus rattus; .III, IX.1971, from Rattus norvegicus.

Timaru .IV.1971, from Rattus rattus; .IV.1971, from Mus musculus.

Family Glycyphagidae

Glycyphagus destructor

Timaru .IV.1971, from Rattus rattus.

S.O. Eutherengona

Family Cheyletidae

Kapiti Island .IX.1966, from Rattus norvegicus.

Christchurch .III.1971, from Rattus rattus; .III.1971, from Rattus norvegicus; .IV.1970, from Mus musculus.

Timaru .IV.1971, from Rattus rattus; .IV.1971, from Mus musculus.

Campbell Island .VIII.1947 from Rattus norvegicus.

S.O. Oribatei

Family Orabatidae

Cuvier Island .VII-VIII.1967 and .VI.1971, from Rattus exulans.

Auckland .IX.1971, from container of Rattus rattus (in alcohol).
Antipodes Island .II.1969, from Mus musculus.

H. THE MICRO-HABITATS OF THE HELMINTH SPECIES RECOVERED

Cestoda

Hydatigera taenaeformis (strobilocercus) was recovered from cysts embedded in the liver tissue.
Hymenolepis diminuta and Hymenolepis nana were recovered from throughout the small intestine and proglottids were occasionally collected from the large intestine.

Trematoda

Plagiorchis muris were collected only from the small intestine.

Nematoda

Capillaria hepatica. Masses of eggs, usually partly calcified, were collected from the surface and interior of the liver.
Capillaria ? sp. These worms occurred threaded in and out of the mucosal lining of the oesophagus and stomach and occasionally in sloughed-off tissue in the stomach contents.
Trichosomoides crassicauda were collected from the contents of the bladder.
Mastophorus muris occurred primarily among the stomach contents. When present in large numbers they were sometimes collected from the oesophagus and the duodenum, possibly the result of post-mortem movement.
Nippostrongylus brasiliensis tended to occur in the lumen of the duodenum but, particularly in the heavier infections, were recovered from throughout the small intestine and infrequently in the caecum.
Heligmosomoides polygyrus occurred in the lumen of both the duodenum and the posterior part of the ileum.
Syphacia obvelata, Syphacia muris and Heterakis spumosa all occurred in lumen of the caecum and colon although, particularly with S. obvelata, isolated worms were detected in the ileum and rectum.

I. CESTODA

Hymenolepis diminuta was recovered from all four rodent species, *Hymenolepis nana* from *Rattus rattus* and *R. norvegicus* and the strobilocerci of *Hydatigera taenaeformis* from *R. norvegicus* and *M. musculus*. Double infections of *H. diminuta* and *H. nana* occurred in one *R. rattus* and three *R. norvegicus*. *H. diminuta* was the only cestode detected in *R. exulans* and occurred in 22 of the 53 hosts examined (Table 23). Four of the 68 *R. rattus* examined (Table 24) and five of the 58 *R. norvegicus* examined (Table 25) were infected with *H. diminuta*. In *Mus musculus* only three of 96 examined contained intestinal cestodes and these were *H. diminuta* (Table 26).

Hymenolepis nana occurred in 14 *R. rattus* (Table 27) and 11 *R. norvegicus* (Table 28). The greatest number recovered from one host was 219 with a mean length of 46 mm. In single or small infections the worms were considerably longer. Although only one of these longer worms was recovered intact several were clearly over 300 mm.

The strobilocerci of *Hydatigera taenaeformis* occurred in the livers of two of 96 mice examined and five of the 58 *R. norvegicus* (Table 29).

J. TREMATODA

Trematodes (*Plagiorchis muris*) were recovered only from *R. exulans* and the infected hosts were collected from only two localities (Table 30). This was the only trematode species collected and the specimens obtained from Kapiti Island were in poor condition. With the hosts they had been fixed in formalin in 1966-7 and subsequently allowed to dry out. Restoration of specimens in 1% trisodium phosphate allowed examination of many anatomical features and gross morphology. Species identification was not possible until the seven specimens from Cuvier Island were obtained in January 1972. All of the diagnostic features discussed by Dollfus (1925) were visible except those in the region of the ventral sucker. The cirrus pouch and the anterior portion of the oviduct were masked by eggs. The lengths of these organs, relative to the ventral sucker, could however be

Table 23 INCIDENCE OF *HYMENOLEPIS DIMINUTA* IN *RATTUS EXULANS* WITH LOCALITY

Locality	Rats examined	Rats infected	Parasites present	Range in parasite numbers	Range in host body weights (in grams)
Burgess I.	7	4	4	1	104 - 162
Hen & Chicken Gp.	1	1	1	1	35
Little Barrier I.	4	0	0	0	-
Cuvier I.	33	6	17	1 - 12	60 - 164
Red Mercury I.	5	0	0	0	-
Kapiti I.	3	0	0	0	-
Total	53	11	22	1 - 12	35 - 164

Table 24 INCIDENCE OF HYMENOLEPIS DIMINUTA IN RATTUS RATTUS WITH LOCALITY

Locality	Rats examined	Rats infected	Parasites present	Range in parasite numbers	Range in host body weights (in grams)
Christchurch	29	2	4	1 - 3	182 - 203
Quail Island	5	1	1	1	117
Dunedin	3	1	1	1	194

Table 25 INCIDENCE OF HYMENOLEPIS DIMINUTA IN RATTUS NORVEGICUS WITH LOCALITY

Locality	Rats examined	Rats infected	Parasites present	Range in parasite numbers	Range in host body weights (in grams)
North Canterbury	8	5	9	1 - 3	211 - 337

Table 26 INCIDENCE OF HYMENOLEPIS DIMINUTA IN MUS MUSCULUS WITH LOCALITY

Locality	Mice examined	Mice infected	Parasites present	Range in parasite numbers	Range in host body weights (in grams)
Timaru	4	3	4	1 - 2	17 - 19

Table 27 INCIDENCE OF HYMENOLEPIS NANA IN RATTUS RATTUS WITH LOCALITY

Locality	Rats examined	Rats infected	Parasites present	Range in parasite numbers	Range in host body weights (in grams)
Auckland	5	4	46	2 - 21	139 - 271
Christchurch	29	10	259	1 - 219	66 - 182

Table 28 INCIDENCE OF HYMENOLEPIS NANA IN RATTUS NORVEGICUS WITH LOCALITY

Locality	Rats examined	Rats infected	Parasites present	Range in parasite numbers	Range in host body weights (in grams)
North Canterbury	12	6	41	1 - 19	201 - 323
Christchurch	21	4	10	1 - 6	163 - 323
Mount Cook	2	1	1	1	336

Table 29 INCIDENCE OF HYDATIGERA TAENAEFORMIS IN RATTUS NORVEGICUS WITH LOCALITY

Locality	Rats examined	Rats infected	Range in parasite numbers	Range in host body weights (in grams)
North Canterbury	8	4	1 - 5	245 - 337
Christchurch	21	1	12	284

followed in serial transverse sections. The general appearance of the specimens is close to the adult P. muris (from mouse) figured by McMullen (1937) differing only in being slightly narrower and more elongated in the region posterior to the testes. These differences may be attributable to variations in fixation and mounting techniques.

Table 30 INCIDENCE OF PLAGIORCHIS MURIS IN RATTUS EXULANS WITH LOCALITY

Locality	Rats examined	Rats infested	Parasites present	Range in numbers of parasites	Range in host body weights in grams
Cuvier I.	33	1	7	7	105
Kapiti I.	3	2	7	3 - 4	63 - 80

Those specimens from Kapiti Island were obtained in September and those from Cuvier Island in January.

K. NEMATODA

Nine nematode species were detected from the four host species examined. Two, Heligmosomoides polygyrus and Syphacia obvelata, were recovered only from Mus musculus and were the only two nematode species present in this host. Mastophorus muris, Capillaria ? sp. and Syphacia muris were recovered from all three species of Rattus. The eggs of Capillaria hepatica were detected in 17 of 53 R. exulans (Table 31) and 3 of 68 R. rattus (Table 32). Nippostrongylus brasiliensis and Heterakis spumosa were recovered from both R. rattus and R. norvegicus while Trichosomoides crassicanda occurred only in R. norvegicus.

Nematode Distributions

Capillaria ? sp. was recovered from the mucosal lining

Table 31 INCIDENCE OF *CAPILLARIA HEPATICA* IN *RATTUS EXULANS* WITH LOCALITY

Locality	Rats examined	Rats infected	Range in host body weights (in grams)
Burgess I.	7	1	151
Hen & Chicken Gp.	1	1	35
Cuvier I.	33	15	73 - 150

Table 32 INCIDENCE OF *CAPILLARIA HEPATICA* IN *RATTUS RATTUS*

Locality	Rats examined	Rats infected	Range in host body weights (in grams)
Auckland	5	3	209 - 271

Table 33 DISTRIBUTION OF *CAPILLARIA* ? SP. WITH THE HOST (*RATTUS EXULANS*)

Region	Rats examined	Rats infected
Oesophagus	50	31
Stomach	48	18

Table 34 INCIDENCE OF *CAPILLARIA*? *SP.* IN *RATTUS EXULANS* WITH LOCALITY

Locality	Rats examined	Rats infected	Parasites present	Range in parasite numbers	Range in host body weights (in grams)
Burgess I.	7	5	16	1 - 6	123 - 162
Little Barrier I.	4	1	6	6	92
Cuvier I.	33	23	146	1 - 26	73 - 164
Red Mercury I.	5	5	21	2 - 10	77 - 119

Table 35 INCIDENCE OF *CAPILLARIA* ? SP. IN *RATTUS RATTUS*

Locality	Rats examined	Rats infected	Parasites present	Host body weight (in grams)
Auckland	5	1	6	102

Table 36 INCIDENCE OF *CAPILLARIA* ? SP. IN *RATTUS NORVEGICUS*

Locality	Rats examined	Rats infected	Range in parasite numbers	Range in host body weights (in grams)
Whale I.	3	2	1 - 4	266 - 275

Table 37 INCIDENCE OF *MASTOPHORUS MURIS* IN *RATTUS EXULANS* WITH LOCALITY

Locality	Rats examined	Rats infected	Parasites present	Range in parasite numbers	Range in host body weights (in grams)
Hen & Chicken Gp.	1	1	4	4	35
Little Barrier I.	4	1	2	2	85
Cuvier I.	33	26	194	1 - 33	73 - 164
Red Mercury I.	5	*	11	-	-
Kapiti I.	3	1	3	3	74

* Pooled sample received after stomach contents analysed.

Table 38 INCIDENCE OF *MASTOPHORUS MURIS* IN *RATTUS RATTUS* WITH LOCALITY

Locality	Rats examined	Rats infected	Parasites present	Range in parasite numbers	Range in host body weights (in grams)
Goat I.	2	2	13	3 - 10	137 - 156
Auckland	5	1	1	1	102
Mt Bruce	7	4	42	3 - 14	137 - 172
Christchurch	29	4	20	1 - 10	120 - 203

Table 39 INCIDENCE OF MASTOPHORUS MURIS IN RATTUS NORVEGICUS WITH LOCALITY

Locality	Rats examined	Rats infected	Parasites present	Host body weights (in grams)
Mt Bruce	10	1	4	148
Kapiti I.	7	1	5	164

Table 40 INCIDENCE OF SYPHACIA MURIS IN RATTUS EXULANS WITH LOCALITY

Locality	Rats examined	Rats infected	Parasites present	Range in parasite numbers	Range in host body weights (in grams)
Burgess I.	7	1	31	31	128
Cuvier I.	33	6	875	5 - 691	26 - 138
Kapiti I.	3	3	88	12 - 53	63 - 80

Table 41 INCIDENCE OF SYPHACIA MURIS IN RATTUS RATTUS WITH LOCALITY

Locality	Rats examined	Rats infected	Parasites present	Range in parasite numbers	Range in host body weights (in grams)
Auckland	5	1	17	17	210
Mt Bruce	7	3	86	2 - 43	137 - 143
Inangahua	7	3	41	10 - 17	152 - 171
Christchurch	29	13	961	1 - 419	117 - 197
Quail I.	5	2	92	11 - 81	33 - 182
Timaru	9	8	119	4 - 31	84 - 202

Table 42 INCIDENCE OF *SYPHACIA OBVELATA* IN *MUS MUSCULUS* WITH LOCALITY

Locality	Mice examined	Mice infected	Parasites present	Range in parasite numbers
North Canterbury rural	20	13	237	1 - 45
Christchurch suburban	47	9	97	3 - 44
" commercial	12	5	204	8 - 166
" laboratory	3	2	14	6 - 8
Quail I.	3	1	7	7
Timaru	4	4	85	10 - 40
McKenzie Country	1	0	0	0
Auckland Is.	3	2	13	3 - 10

of the oesophagus and stomach (Table 33) and was most prevalent in R. exulans (Table 34). It did however occur once in R. rattus (Table 35) and twice in R. norvegicus (Table 36) in northern localities.

Mastophorus muris occurred in R. exulans from five localities (Table 37), in R. rattus from four localities (Table 38) and once each in two localities from R. norvegicus (Table 39).

Syphacia muris was the most widely distributed nematode species. From R. exulans it was present in three localities (Table 40), from R. rattus in six localities (Table 41) and from R. norvegicus in one locality, i.e. Kapiti Island where a juvenile host had 31 S. muris.

From five infected R. exulans 13 male and 171 females S. muris were collected while nine R. rattus had eight male and 265 female S. muris. In a sample of 11 infected M. musculus five male and 224 female S. obvelata were collected.

Syphacia obvelata was the most widely distributed of the helminth species infecting M. musculus (Table 42) and had the highest incidence, occurring in 36 of the 96 mice examined. Mice from commercial premises showed the highest incidence of infection with S. obvelata and those from rural areas the least (Table 43). If one exceptionally heavily infected host, with 166 S. obvelata, is ignored then the means and range in numbers per host in each habitat are comparable (c.f. values in parenthesis in Tables 42, 43 and 52).

Table 43 INCIDENCE OF SYPHACIA OBVELATA IN MUS MUSCULUS WITH HABITAT

Habitat	Mice examined	Mice infected	Parasites present	Range in parasite numbers
Commercial premises	25	11	303 (137)	6-166 (6-40)
Suburban areas	50	10	99	1-44
Rural areas	21	15	250	1-45

The third Oxyurid species Heterakis spumosa was collected from 16 hosts. Ten of these were R. rattus (Table 44) and the other six were R. norvegicus (Table 45).

Nippostrongylus brasiliensis had a wide geographical distribution occurring in six localities from R. rattus (Table 46) and four localities from R. norvegicus (Table 47). These worms tended to occur in the duodenum, but in heavy infections (50-345 worms) they were collected from along the entire length of the small intestine and occasionally from the caecum.

Heligmosomoides polygyrus was present in ten mice; once from rural North Canterbury, once from commercial premises in Christchurch and eight times from suburban areas in Christchurch. The incidence was low with only one mouse having thirteen and the others less than four H. polygyrus.

Although occurring only in R. norvegicus, Trichosomoides crassicauda was recovered from Kapiti Island, the South Island and Campbell Island (Table 48).

With S. obvelata in M. musculus and S. muris in R. rattus Spearman-Rho rank correlations failed to produce significant relationships between host body-weights and infection sizes. With S. muris in R. exulans however an inverse relationship occurred (0.709) which was significant at the 0.05 confidence level (see Appendix C).

In R. norvegicus a positive correlation was obtained between host body-weight and the numbers of N. brasiliensis present per infection. This was also significant at the 0.05 level (see Appendix D).

L. THE HELMINTH FAUNA OF RATTUS EXULANS

Six helminth species were collected from R. exulans (Table 49). These were the cestode Hymenolepis diminuta, the trematode Plagiochis muris and four nematode species Capillaria ? sp., Capillaria hepatica, Mastophorus muris and Syphacia muris. The ratios of male to female hosts infected by each species did not vary significantly from 1:1 although egg from C. hepatica occurred in 14 male and only three female rats. Owing to the distribution of this host and the few potential collectors available only eight

Table 44 INCIDENCE OF HETERAKIS SPUMOSA IN RATTUS RATTUS WITH LOCALITY

Locality	Rats examined	Rats infected	Parasites present	Range in parasite numbers	Range in host body weights (in grams)
Auckland	5	3	24	3 - 11	102 - 271
Christchurch	29	5	103	2 - 70	72 - 220
Dunedin	3	2	14	4 - 10	158 - 194

Table 45 INCIDENCE OF HETERAKIS SPUMOSA IN RATTUS NORVEGICUS WITH LOCALITY

Locality	Rats examined	Rats infected	Parasites present	Range in parasite numbers	Range in host body weights (in grams)
North Canterbury	4	2	32	3 - 19	278 - 323
Christchurch	21	4	49	5 - 21	148 - 327

Table 46 INCIDENCE OF *NIPPOSTRONGYLUS BRASILIENSIS* IN *RATTUS RATTUS* WITH LOCALITY

Locality	Rats examined	Rats infected	Parasites present	Range in parasite numbers	Range in host body weights (in grams)
Goat Island	2	2	64	2 - 62	137 - 156
Auckland	5	1	37	37	102
Mt Bruce	7	4	88	1 - 73	105 - 164
Inangahua	7	3	21	2 - 12	152 - 200
Christchurch	29	3	32	7 - 16	66 - 203
Dunedin	3	1	11	11	158

Table 47 INCIDENCE OF NIPPOSTRONGYLUS BRASILIENSIS IN RATTUS NOVEGICUS WITH LOCALITY

Locality	Rats examined	Rats infected	Parasites present	Range in parasite numbers	Range in host body weights (in grams)
Mt Bruce	10	2	8	4	41 - 44
Kapiti I.	7	5	162	3 - 114	98 - 330
North Canterbury	8	2	54	3 - 51	284 - 293
Christchurch	21	8	599	1 - 345	46 - 327

Table 48 INCIDENCE OF *TRICHOSOMOIDES CRASSICAUDA* IN *RATTUS NORVEGICUS* WITH LOCALITY

Locality	Rats examined	Rats infected	Parasites present	Range in parasite numbers	Range in host body weights (in grams)
Kapiti I.	7	1	9	9	330
North Canterbury	12	3	10	2 - 5	245 - 323
Christchurch	21	2	11	3 - 8	284 - 364
Campbell I.	3	1	5	5	239

Table 49 INCIDENCE OF HELMINTH SPECIES IN *RATTUS EXULANS* WITH HOST BODY-WEIGHTS

Host body-weight class (in grams)	*Hymenolepis diminuta*		*Plagiorchis muris*		*Capillaria* ? sp.		*Capillaria hepatica*		*Mastophorus muris* *		*Syphacia muris*	
	Rats ex.	Rats inf.	Rats ex.	Rats inf.	Rats ex.	Rats inf.	Rats ex.	Rats inf.	Rats ex.	Rats inf.	Rats ex.	Rats inf.
- 20	1	0	1	0	1	0	1	0	1	0	1	0
21 - 50	2	1	2	0	2	0	2	1	2	1	2	1
51 - 80	11	3	11	2	11	5	11	4	10	6	11	4
81 - 110	22	4	22	1	22	15	22	5	22	14	22	3
111 - 140	10	1	10	0	10	8	10	3	8	3	10	2
141 - 170	7	2	7	0	7	6	7	4	5	5	7	0

* *M. muris* occurred also in a pooled sample of stomach contents from the five hosts not included in this column.

samples, from six localities, were examined. No seasonal or monthly trends in parasite incidence could thus be followed but the absence of S. muris in the June sample from Cuvier Island (21 rats) suggests a seasonal variation. S. muris was present in the January sample from Cuvier Island.

Little published information is available concerning the size at which the New Zealand race of R. exulans becomes mature. Marples (1955) concluded that they were larger than those in some places in the Pacific. The data presented by Watson (1956) suggests that female R. exulans become sexually mature between 40 and 50 grams body weight. No female rats in this range were collected but all females over 60 grams were mature. The smallest male with scrotal testes was 62 grams but seasonal testes "migration" may occur as one male rat of 73 grams had abdominal testes in June. C. hepatica, M. muris, S. muris and H. diminuta all occurred over a range of host body weights including immature hosts. P. muris occurred in three adult hosts and Capillaria ? sp. was present throughout the full range of mature hosts (i.e. 73 grams upward).

Plagiorchis muris was the only helminth restricted to R. exulans although Capillaria ? sp. and C. hepatica had very limited distributions in their other hosts (Tables 35, 36 and 32).

M. THE HELMINTH FAUNA OF RATTUS RATTUS

Two cestode and six nematode species were recovered from Rattus rattus. Three of these helminth species occurred only in hosts from commercial premises; Capillaria ? sp. and C. hepatica in Auckland and H. nana in both Auckland and Christchurch. The remaining species were recovered from a range of habitats. This wide range of habitats and the year round constancy of environmental conditions in grain stores etc. render an unqualified seasonal analyses of the R. rattus fauna meaningless. As geographic coverage was the aim of this survey an uneven monthly distribution of hosts was obtained. Both cestode species, M. muris, N. brasiliensis, S. muris and H. spumosa were found however over a sufficient range of months to suggest that they are present throughout the year (refer Appendix E).

The criteria for sexual maturity of perforated vagina and scrotal testes show that both sexes become mature at 75-85 grams. S. muris, H. nana and N. brasiliensis were present in juvenile and mature rats (Table 50) while the remainder tended to be distributed throughout the mature hosts.

Sample sizes were large enough to allow a statistical comparison of the ratio of male to female hosts infected only in S. muris and N. brasiliensis. In both cases the difference was insignificant.

No comparable relationship between S. muris infection size and host body-weight, as detected in R. exulans, was found in R. rattus. None of the helminth species were restricted to R. rattus.

N. THE HELMINTH FAUNA OF RATTUS NORVEGICUS

Of the three cestodes and six nematode species infecting this host only Trichosomoides crassicauda was not recovered from other hosts. Several parasite species were obtained at widely separated times of the year (see Appendix E) but the host samples obtained were not structured to allow valid monthly or seasonal comparisons. N. brasiliensis was the only helminth to be widely distributed throughout all host weight classes (Table 51) and along with the solitary record of S. muris was the only helminth infecting a juvenile rat. The sexual maturity criteria used indicate that R. norvegicus reach maturity at about 115-125 grams in both sexes. There was a tendency for the size of N. brasiliensis infections to increase as the host body-weights increased (Spearman-Rho rank correlation +0.584, significant at the 0.05 confidence level).

Only H. nana, N. brasiliensis and T. crassicauda were collected from more than two localities while H. diminuta, H. taenaeformis and H. spumosa were recovered only from Canterbury in this host. As in R. rattus the oesophageal nematode (Capillaria ? sp.) was recovered only from the northern part of the North Island. Insufficient infected hosts were available to allow a comparison of the infectability of male and female hosts for each helminth species.

Table 50 INCIDENCE OF HELMINTH INFECTIONS IN *RATTUS RATTUS* WITH HOST BODY-WEIGHT

Body-weight class (in grams)	0-50	51-80	81-110	111-140	141-170	171-200	201-	Total
No. rats examined	6	9	11	12	16	7	7	68
H. diminuta	0	0	0	1	0	3	0	4
H. nana	0	2	1	1	1	1	3	9
M. muris	0	0	1	3	4	2	1	11
N. brasiliensis	0	1	2	2	5	3	1	14
S. muris	2	4	6	5	7	4	2	30
H. spumosa	0	0	3	0	2	2	3	10
Capillaria? sp.	0	0	1	0	0	0	0	1
C. hepatica	0	0	0	0	2	1	0	3

Table 51 INCIDENCE OF HELMINTH INFECTIONS IN *RATTUS NORVEGICUS* WITH HOST BODY-WEIGHT

Body-weight class (in grams)	0-50	51-110	111-170	171-230	231-290	291+	Total
No. rats examined	15	7	8	9	9	11	59
H. diminuta	0	0	0	1	1	3	5
H. nana	0	0	1	4	2	4	11
H. taenaeformis	0	0	0	0	2	3	5
M. muris	0	0	2	0	0	0	2
N. brasiliensis	3	2	2	4	2	4	17
S. muris	0	1	0	0	0	0	1
H. spumosa	0	0	1	3	1	1	6
Capillaria ? sp.	0	0	0	1	1	0	2
T. crassicauda	0	0	0	0	4	3	7

0. THE HELMINTH FAUNA OF MUS MUSCULUS

Two cestode and two nematode species were collected from this host. Of these the nematode Syphacia obvelata was the most prevalent and occurred in 7 different localities (Table 42). The incidence of S. obvelata increased with host body-weight (Table 52). As with the other hosts the nature of collection did not permit valid monthly or seasonal comparisons.

The criteria used show that mice in Canterbury reach sexual maturity between 10.5 and 12.5 grams. S. obvelata was the only helminth species recovered from juvenile mice (Table 52).

No preferential infection of male or female hosts with any of the helminth species could be determined. S. obvelata and H. polygyrus were collected only from M. musculus. H. diminuta occurred from only one locality, a grain store in Timaru, where the hosts lived in close association with R. rattus. Cestodes collected at Massey University about 1964 from laboratory mice by Dr W.C. Clark have subsequently been identified as H. diminuta and are the only other record of an intestinal cestode from M. musculus in New Zealand.

The strobilocerci of H. taenaeformis were detected in two adult mice, one from laboratory stocks and one from a Christchurch suburban property.

Table 52 INCIDENCE OF SYPHACIA OBVELATA IN MUS MUSCULUS WITH HOST BODY-WEIGHT

Host body-weight (in grams)	Mice examined	Mice infected	Parasites present	Range in parasite numbers
0-12.5	24	8	196	1-166 (1-16)
12.6-18.5	49	16	295	1-45
18.6-	22	12	160	3-37
All weights	95	36	651	1-166

CHAPTER 4

DISCUSSION

A. SIPHONAPTERA

Of the five species of rodent fleas described from New Zealand three were classified by Smit (1965) as cosmopolitan and the remaining two as Australian.

(i) Origins of "Cosmopolitan" species

In this category are Nosopsyllus fasciatus, Xenopsylla cheopis and Leptopsylla segnis. All three have virtually world-wide coincident distributions with Rattus rattus and occur also on R. norvegicus in many places (Smit, 1965). N. fasciatus and L. segnis are widespread as parasites of Mus musculus.

The origins of these flea species in New Zealand are likely to be as varied as those of its R. rattus stocks. If, as postulated by Maclean (1955), the Plague outbreaks in New Zealand between 1900 and 1911 resulted from three separate introductions, then, up until that time at least, the introductions of R. rattus were as frequent and as varied as the trade routes would allow. N. fasciatus was recorded from both Hen and Little Barrier Islands on R. exulans by Smit (1965). Its discovery on this host from Burgess and Cuvier Islands, which in conjunction with the previous two localities have apparently never had other rodent species introduced to them, suggests that this flea has been introduced to those islands by R. exulans. The large numbers of this flea recovered from Cuvier Island (156 from 33 hosts in 1971) also make Smit's assumption (p.35), that this species is an accidental parasite of R. exulans, difficult to accept.

Although these populations of N. fasciatus were probably introduced with R. exulans those at other localities (Smit, 1965; Blakelock and Allen, 1959) may be presumed to have been introduced on R. rattus and R. norvegicus.

The collection of X. cheopis, the so-called oriental plague flea, from Auckland was not unexpected. Maclean (1955) stated that "X. cheopis is certainly to be found in Auckland today" and its presence on rats killed at Bycroft's Mill (Shortland St) shows that this species is not confined to the waterfront area.

Previous writers (Maclean, 1955 and Smit, 1965) have stressed the known temperature tolerances of X. cheopis when discussing its distribution and the consequent implications regarding the plague. The presence of X. cheopis on large numbers of rats in the port of Liverpool (Newstead and Evans, 1921) shows that a suitably warm environment is readily provided by many large commercial premises in areas where the external air temperature frequently drops below the specified lower breeding limit for X. cheopis of 60°F.

Leptopsylla segnis was recovered from R. rattus, R. norvegicus and M. musculus, all of which were previously recorded as hosts for this species in New Zealand (Blakelock and Allen, 1959; Smit, 1965). L. segnis was the most frequently encountered flea on M. musculus, and although it is the most common cosmopolitan flea of this host, it was also present within the same host populations as the rat flea N. fasciatus on both of its other rodent hosts. From five infected R. rattus trapped on Quail Island in April and May 74 L. segnis and three N. fasciatus were recovered, suggesting that in this locality L. segnis was at no disadvantage on R. rattus.

(ii) Origins of the "Australian" species

The two species placed in this category by Smit (1965) were Pygiopsylla hoplia and Xenopsylla vexabilis both of which he stated were wholly associated with R. exulans. R. vexabilis was recovered only from R. exulans in localities where it occurred in isolation from other rodent species (Fig. 2). The distribution of P. hoplia was more extensive. On Red Mercury Island and Kapiti Island its presence is clearly associated with R. exulans. On the islands of the Motukawao Group and on Whale Island the occurrence of this flea on R. rattus and R. norvegicus can be explained by the probable replacement of R. exulans by these hosts.

Finding this flea on R. norvegicus from the banks of the Heathcote Valley stream is more difficult to explain. R. exulans appears to have been absent from the Christchurch region for about one hundred years. Smit (1965) stated that P. hoplia is a flea of small mammals occurring in Australia and Tasmania. It is possible that this record is the result of a recent introduction through the port of Lyttelton.

The introduction of R. norvegicus is usually attributed to the whaling and sealing vessels operating around New Zealand in the early 19th century. Many of these ships were based in Australia. While the possible introduction of P. hoplia, in some localities, from this source cannot be discounted the two early whaling or sealing centres where P. hoplia has been collected, Kapiti Island and Codfish Island (M.J. Daniel, pers. comm.) both have R. exulans populations. The latter in the absence of R. norvegicus.

The zoogeographical problems posed by P. hoplia and X. vexabilis appear to be compounded by the assumptions that they are Australian species and that R. exulans is not the original host. Their extensive host range in Australia and P. hoplia's success on R. rattus and R. norvegicus in New Zealand suggests a possible common origin for these flea species other than Australia.

The movement of R. exulans eastward across the Pacific to the north of Australia (Tate, 1935) would have provided an opportunity for other small mammal species to come into contact with R. exulans in this region. These other species could have acted as vectors for these fleas from, for example, New Guinea to mainland Australia. The presence of X. vexablis on R. exulans near both its northern and southern geographic limits of distribution (Hawaii and New Zealand respectively) further supports this but more extensive flea surveys of this host are necessary for confirmation.

(iii) Incidence of Fleas

The incidence of fleas on all host species (Table 5) was primarily a reflection of trapping methods and secondarily of host specific factors. Fur examination methods

were relatively unimportant. While the brushing and direct examination of hosts was less efficient in detecting other ectoparasite groups, for fleas the difference was not as great.

The greater incidence and numbers of fleas on R. exulans (Table 5), and to a lesser extent R. rattus, may be the product of several factors. The flea species involved could be the determinant but N. fasciatus, the most prevalent flea on R. exulans (Table 10) was also widespread on R. rattus (Table 11) and R. norvegicus (Table 12). The inverse relationship between both incidence and flea numbers with mean host species body-size is contrary to most overseas findings (Mohr, 1961).

Mohr (1961) suggested with his examples that a direct relationship would be the result of: (1) the difference in amount of host surface area available for infestation, or exposure to it and (2) differences in standard home range. Behavioural and physiological variation especially regarding time and presence in sub-habitats and cleansing ability, were of secondary importance.

In this survey the major factors, for fleas and lice at least, appear to be the behavioural and physiological variations mentioned above with factors (1) and (2) of minor importance. It is probably significant that most of the R. exulans are from relatively small islands and most of the R. rattus from islands or confined areas such as warehouses, while the R. norvegicus samples appear to have had greater geographical ranges available.

Correspondence received with two of the R. exulans samples, and the trapping success at these localities, suggested that the populations on these islands were very dense. Personal observations of poisoning programmes and fumigations, in the warehouses etc. where samples were obtained, confirmed high densities of R. rattus there. The high incidence of intra-specific contact is a likely determinant of these high infestations. Other small mammal studies have shown physiological derangements as a consequence of high population stresses (Bull, 1958) which could well contribute to reduced resistance to parasite species.

A detailed examination of the relevant environmental

factors is beyond the scope of this survey but the analyses of all host species shows that these factors do not allow for either sex of host to be preferentially infested with fleas. The sex ratios within the flea species showed a significant deviation from a 1:1 ratio with L. segnis. Only N. fasciatus and P. hoplia however, of the other species, had sufficient numbers to test for a significant difference and both were close to a 1:1 ratio.

For these three species the sizes of both flea and host samples were large enough to be representative of the flea populations on trappable rats. The samples were not adequate however to show that the fur fauna is also representative of the total flea fauna. Previous studies (Cole and Koepke, 1946) have noted that N. fasciatus visits the host only to feed leading to an under-estimation of its abundance. Twenty-four N. fasciatus were collected from rats' nests. Of these 21 were males. Deletion of these fleas from the total N. fasciatus sample leaves 96 males and 122 females with one undetermined (damaged). The probability that this distribution could be drawn from a 1:1 ratio is still greater than 0.10 but the difference from the total sample demonstrates the importance of differentiating between the host fauna and the total fauna in flea populations.

Because of this distinction, and the differences introduced by trapping methods, the quantitative aspects of seasonal presence have not been used as the basis for analysis of flea biology. L. segnis and N. fasciatus were recovered throughout the year. The limited periods of detection for the other three species are a consequence of the lack of samples. Limited detection cannot be accepted as evidence of any seasonal trends in incidence.

The smallest rodent hosts found to be infested were nestlings in R. rattus, R. norvegicus and M. musculus. Only two R. exulans of nestling size were recovered and the proportion of juveniles in the samples of R. exulans is too small to determine that hosts of less than 50 grams body-weight were unlikely to be infested. With the other host species the range in host body weights is from nestlings to large adults (Tables 11, 12 and 13). The distribution

through these ranges was relatively even.

In epidemiological surveys the value of total flea indices has been justifiably questioned (Cole and Koepke, 1946) owing to considerable differences in physiological characters, geographical distribution, and efficiency as vectors of diseases. The analyses presented here (Table 5) constitute an index of parasitism on collection, and are not examinations of specific disease vectors. Even analyses of single flea species expressed as indices from surveys such as this, fail as accurate measures of flea abundance except for species living almost exclusively on the hosts and subjected to uniformity in collection techniques not practical in this survey.

B. ANOPLURA

(i) Host Specificity

Host specificity in lice was much greater than in most of the other parasite groups (Table 14). Hoplopleura pacifica was not restricted to R. exulans but was present on R. norvegicus only where it was living in close association with R. exulans i.e. on Kapiti Island. H. pacifica has been recorded elsewhere from R. rattus (Johnson, 1964) but has not been recorded from this host in New Zealand. Polyplax spinulosa is a cosmopolitan parasite of both R. rattus and R. norvegicus (Johnson, 1964) and occurred widely on both species in New Zealand. The presence of P. spinulosa on the single R. exulans probably represents stragglers obtained in captivity and until P. spinulosa's presence on R. exulans from this locality is confirmed they will be treated as such. Only H. pacifica was recorded from Hen Island by Ford-Robertson and Bull (1966). The entire sample of R. exulans examined was infested with H. pacifica and the numbers of lice were consistently high (Table 14). The rat obtained from the Hen and Chicken Islands (discussed above) is distinctly atypical. The large number of lice recovered (4004) was probably correlated with either the factors associated with its confinement prior to death or the physical cause of death.

P. serrata was recovered only once. This was from a mouse trapped on Quail Island. The only previous record of

P. serrata in New Zealand is from a preserved white mouse from the Dominion Museum (R.L.C. Pilgrim, pers. comm.). This louse is somewhat smaller than the other two species and its low rate of detection could well be a consequence of collection methods. No lice were recovered from the 101 mice examined in the preliminary study of this survey and the three specimens obtained were from one of the 19 hosts examined by the modified Buxton/Hopkins fur dissolving method.

(ii) Anopluran population characteristics

Few studies dealing with the dynamics of Anopluran populations on rodents have been published. Only that of Beer and Cook (1968) attempts to allow for long term environmental influences while using efficient louse detection methods. H. pacifica is the most common Anopluran collected from R. exulans and R. rattus ssp. in the Australian and Oriental regions (Johnson, 1964) but the structure of H. pacifica populations has received little attention. A ratio of adult to nymphal lice of close to 1:1 has been noted for other species of Hoplopleura (Cook and Beer, 1955). The similar ratio encountered here suggests that H. pacifica's population structure will not be significantly different. The constancy of this ratio with month of host collection and most of the larger host body-weight classes ($>$ 80 grams) supports this.

As in Cook and Beer's study (1955) the average Anopluran population size varied with host weight class and significantly larger average populations occurred on male hosts. On the smaller rats ($<$ 80 grams) not only were these populations smaller but they contained many more nymphs than adult lice.

(iii) Incidence of Anoplura

After the myobiid mite, Radfordia ensifera, the louse P. spinulosa was the most widely distributed parasite of R. rattus and R. norvegicus. As this louse was present on the smallest hosts with fur, of both species (Tables 15 and 18), it can be assumed that infestation can occur in the nest or at any time throughout life (Fig. 3). Lice were not recovered from R. rattus during June, July and December but the number of hosts concerned were only 1, 1 and 4 respect-

ively. The numbers and proportion of nymphs to adult lice were greatest on those hosts collected during September but consideration of the quantitative aspects of the louse fauna of both this host and R. norvegicus becomes academic when the ectoparasite collection methods are discussed with respect to louse numbers (see pages 95-98).

Polyplax spinulosa occurred on R. norvegicus in all months except July and December but, in both these months, only one rat was examined. The greatest numbers of lice per host were collected in October but the sample sizes involved in this survey are insufficient to conclude seasonal variations in numbers. At no time did the number of nymphal P. spinulosa equal or exceed those of the adults.

(iv) Anopluran distribution on the host

The eleven R. exulans examined to determine the louse distribution on this host (Table 19) showed that the greatest concentration of both adult lice and nymphs was on the back (Fig. 4). The proportion of adults to nymphs in this region did not differ significantly from the 1:1 ratio discussed earlier. The region where the second largest proportion of adults occurred was the belly and flanks (Fig. 4). In this region the ratio of adults to nymphs significantly favoured the adults. The numbers of the head and neck were not significantly different from a 1:1 ratio but on the crutch significantly more nymphs occurred. The head, back and total numbers can all be accepted as being from a total population with a 1:1 ratio of adults to nymphs.

The area of the belly and flanks is slightly larger than that of the back (Fig. 4) so that the numbers of lice in each region is important. The role of grooming in determining louse numbers on Mus musculus has been analysed by several authors (Murray, 1961; Clifford, Bell, Moore and Raymond, 1967) and grooming must be accepted as a major determinant of louse distribution on R. exulans. The low proportion of adult lice in the crutch region may be related to their removal during grooming. The nymphs, being smaller, may have been less readily removed or may be the first to colonise vacant (groomed) areas. Murray (1961) stated that P. serrata will move readily from the ungroomed areas to the

groomed areas from which lice have been removed.

The reason for the small proportion of nymphs on the head and neck is not immediately obvious but could again be related to grooming or other factors determining the deposition and survival of eggs in this region.

(v) Origins of Anopluran Species

Lice spend their entire life on the host and have developed a high degree of host specificity relative to other ectoparasite groups. All louse species recorded here were recovered from their type species as designated by Hopkins (1949). As H. pacifica is now known from six localities in New Zealand from R. exulans and only occurred on R. norvegicus where this host was in contact with R. exulans it is certain that this louse has been introduced to New Zealand with R. exulans. The isolation of such localities as Burgess, Hen, Little Barrier, Cuvier and Red Mercury Islands from the other rodent species virtually confirms this.

P. serrata's solitary record on M. musculus, its type host, makes it unlikely that any other source could be responsible for its introduction. P. spinulosa occurred extensively on R. rattus and R. norvegicus and although the latter is its type host this louse is a cosmopolitan parasite of both hosts and has undoubtedly been introduced on both. Only from the Campbell Island sample can the original host be assumed to be R. norvegicus owing to the absence of R. rattus there.

C. ACARINA

Ectoparasitic mites may live on the surface of the host feeding on exudations and abrading the surface, or they may penetrate the surface tissue. The distinction between parasitic and non-parasitic status in mites is often indeterminate and to determine may require more information than the mere association of mite and host. With many mite species this is lacking so that in the presentation of the Acarine fauna recovered the categories A, B and C have been used. Those with structurally modified limbs to aid their parasitic mode generally show a higher degree of host specificity than the others. All in this group (category

A), like the lice, spend their entire life cycle on the host and are spread by intra-specific contacts. With this type of life cycle they have been free to develop a higher degree of host-specificity. Category B includes the remainder of those mites which have been classified by previous authors as parasitic. Some of these classifications have been subsequently doubted and these are discussed later. Those in Category C include some of the most frequently recorded mites on rodents, i.e. many of the mites of stored products. These are all non-parasitic and occur on rodents because of accidental contacts in their shared habitats.

Distribution and Incidence

(i) Category A

Three of the species recovered were members of the family Myobiidae (Acariformes). Radfordia ensifera was detected on 115 hosts (Table 20) and was the most prevalent and widely distributed parasite recovered; occurring from the northern off-shore islands to sub-antarctic Campbell Island. Although obtained from every locality sampled where any of the Rattus species were collected (Table 1, Fig. 2), the quantitative aspects of the samples obtained must be considered in terms of the ectoparasite collection method used (Tables21 and 22). The samples collected using the KOH dissolving technique show a mean population of over 50 R. ensifera per host from all three species (Tables20, 21 and 22). This mite was largely confined to the head and mid-dorsal region of the back on the hosts. R. ensifera has not previously been recorded from New Zealand but is a cosmopolitan parasite of both R. norvegicus and R. rattus, and has been collected from R. rattus in Australia (Domrow, 1967). Its absence from ectoparasite surveys both in New Zealand and elsewhere is almost certainly a consequence of its size (300 μ in length) and the detection methods used.

Radfordia affinis is a parasite of Mus musculus in both Europe and North America (Ewing, 1938). Although a relatively restricted distribution in New Zealand was found it was recorded from two different areas in Christchurch, in Akaroa and in the Auckland Islands showing that this previously unrecorded parasite is well established in these

regions at least. This "restricted" distribution is probably a reflection of the restricted distribution of the M. musculus sampled (Table 1, Fig. 2).

The third myobiid mite collected was the cosmopolitan, and much described, Myobia musculi. Its widespread distribution on M. musculus is well documented and its previously known presence on both laboratory and feral mice (Whitten, pers. comm.) in New Zealand make its extensive distribution within this country from at least Wallaceville in the north (Whitten, pers. comm.) through the South Island and the sub-antarctic Auckland and Antipodes Islands easy to appreciate.

The third Category A parasite of M. musculus recorded in this survey, Myocoptes musculinus, was also previously known from both laboratory and feral mice at Wallaceville (Whitten, pers. comm.). Its absence, in the survey, from feral mice in the South Island may be the consequence of collection methods used or indicative of a limited distribution of this parasite within New Zealand. The finding of this species on the Auckland Island mice and the laboratory stocks makes the first alternative the most likely as these account for six of the 19 mice examined using the fur dissolving technique.

The life histories of the three mouse parasites discussed above have been determined (Grant, 1942; Smith, 1955 and Watson, 1960) but no extensive quantitative studies have been completed and the population dynamics are largely unknown.

The remaining mite species in this category was Notoedres muris. This has previously been recorded in New Zealand from R. norvegicus (Whitten, 1962) and from the hedgehog, Erinaceus europaeus, (Heath, Rush-Munroe and Rutherford, 1971). Sweatman (1962) recorded Notoedres sp. from both R. exulans and R. rattus. N. muris was recovered from both R. rattus and R. norvegicus during this survey but none of the 53 R. exulans examined showed any evidence of the lesions typical of notoedric mange. Sweatman's record of Notoedres on R. exulans was from Kapiti Island and probably represented a cross-infection from the R. norvegicus present there.

(ii) Category B

Members of this category were all in the sub-order Mesostigmata (O. Parasitiformes). The Dermanyssidae were represented by Dermanyssus gallinae which has previously been recorded in New Zealand but not from this host (R. exulans). Its occurrence must be considered accidental as it was noted only once and is not indicative of a close association between R. exulans and the usual hosts. Evans and Till (1966) have stated that D. gallinae is primarily an avian parasite of world-wide distribution which will attack mammals in the absence of its normal hosts. This host was caught adjacent to the lighthouse fowl-run on Cuvier Island and may have been acquired from there. Evans and Till (1966) list the domestic fowl as a normal host for this parasite.

Ten species of Laelapidae were recovered including five species of Hypoaspis. The records of H. nidicorva on R. exulans from Cuvier Island and on R. norvegicus near the Christchurch estuary are of interest as the only previous record of this species was from a jackdaw's nest in a cave in Great Britain (Evans and Till, 1966). H. sardoa is probably a predator or scavenger in the nest debris and its presence on mammals fortuitous (Evans, et. al. 1961) however it has commonly been found on rodents and included in their parasite lists. As with H. miles and H. nidicorva there is insufficient information available on their biology to determine whether they are parasitic on rodents or not. Three of the species of Hypoaspis occurred exclusively on R. exulans from off-shore islands and a fourth on R. norvegicus from Whale Island where this host may have recently replaced R. exulans. Here R. norvegicus were infested with Pygiopsylla hoplia (Siphonaptera) which is normally present on R. exulans and two hosts examined from Whale Island were also infected with the oesophageal nematode Capillaria ? sp. which was normally restricted to R. exulans. After reviewing their effect on mutton birds there, Imber (1971) stated that the invasion by R. norvegicus of the island may have been a fairly recent event. The further record of the remaining species, H. nidicorva, also on R. exulans suggests that these mites were members of the New Zealand Acarine fauna, probably in

association with R. exulans, prior to the introduction of the other three rodent species present here.

Androlaelaps casalis was collected only once. This species is widely distributed in a variety of habitats. It is undoubtedly a predator of tyroglyphid mites and is also found in the nests of small mammals, birds and bees (Hughes, 1961) although Evans and Till (1966) have reported that heavy infestations of female mites on rodents are common and blood has been observed in these.

Eulaelaps stabularis occurred on several occasions from R. exulans (all Cuvier Island) and from M. musculus. Although Eveans, Sheals and Macfarlane (1961) stated that this species was probably a predator or scavenger in nest debris, and its presence on mammals fortuitous, Hora (1934) reported that this species was commonly found in association with rodents and moles with the mites forming large brown scales on the host's body and both sexes are frequently found gorged with blood. The record of E. stabularis on R. exulans caught in the lighthouse fowl-run on Cuvier Island may be the result of a transfer of this mite from stored products at the lighthouse to R. exulans rather than having been introduced on R. exulans.

Haemogamassus pontiger has been frequently collected from rodents or their nests and is probably cosmopolitan. Hughes (1959) noted that in these habitats it has been found containing blood but it also occurs regularly among Acarid mites on stored grain and does not then contain blood. Evans, et. al. (1961) have suggested that it can feed on blood but cannot pierce the skin. This mite was collected from Timaru and Dunedin on R. rattus, and from Christchurch on M. musculus, in grain stores.

Hirstionyssus latiscutatus was collected on R. rattus in several localities from Auckland to Dunedin. It was also recovered from R. norvegicus and M. musculus. The nymph obtained from R. exulans on Cuvier Island cannot be assumed to be H. latsicutatus. This species has been commonly found on the bodies of small mammals but Evans, et. al. (1961) pointed out that, although often cited as a parasite, evidence on its food habits is lacking.

Myonyssus decumani is a common inhabitant of the nests

of M. musculus in Europe (Hora, 1934) and occurred twice in this survey from M. musculus. As with H. latiscutatus Evans, et. al. (1961) also pointed out the lack of evidence on its food habits.

(iii) Category C

The wide range of mite species present in this category has been outlined and indicates the extensive Acarine fauna which must share the same habitats as these hosts. Asca species are not uncommon in rodent fur and may be scavengers. Proctolaelaps hypudaei was collected from M. musculus during both 1970 and 1971 in Christchurch. Hughes (1961) stated that this species was probably mycophagous in habit but noted Evan's (1957) suggestion that it may use small mammals as a means of distribution.

The two species of Macrochelidae are of interest as they constitute the only two known records of these species in New Zealand.

Among the Acariformes the Cheyletidae in this category were the most widespread, occurring in several grain stores, rubbish dumps and sub-antarctic Campbell Island. These are probably free-living predatory species and many have been found in small mammal nests (Hughes, 1961 p.181) and others are grain inhabiting (Sinha, 1963).

The Orabatidae were widely distributed but as these are generally vegetarian it can be assumed their occurrences were accidental. Acaridae occurred widely on R. exulans from off-shore islands and on R. rattus and M. musculus in grain stores. Many species have been recorded elsewhere in this latter habitat and Glycophagus destructor is the most common pest of stored grain in many areas (Sinha, 1963).

D. CESTODA

Hymenolepis diminuta infected all four host species and had previously been recorded from R. exulans (Ford-Robertson and Bull, 1966). Blakelock and Allen (1959) reported this parasite from a sample of R. rattus and R. norvegicus collected in Wellington but failed to distinguish between the host species. H. diminuta is a

cosmopolitan parasite of both rats and mice and has occasionally been recorded in children (Riley and Shannon, 1922; Keller, 1931), being contracted by the consumption of insufficiently cooked foodstuffs made from grain infested by any of the variety of intermediate hosts of this species. During this survey H. diminuta was recovered from flour mills in both Christchurch and Dunedin in R. rattus and from a grain store in Timaru in M. musculus.

In R. exulans this species was recorded from three new localities, Burgess and Cuvier Islands as well as an unspecified island in the Hen and Chicken group. It had previously been collected from Little Barrier Island (Ford-Robertson and Bull, 1966). In the other three host species this parasite was recovered from South Island samples (Tables 24, 25 and 26) between North Canterbury and Dunedin. This species is probably not as limited in distribution as shown by Blakelock and Allen's (1959) record and the specimens of H. diminuta collected from laboratory mice at Massey University.

Hymenolepis nana occurred in both R. rattus and R. norvegicus in several localities (Tables 27 and 28). Smyth (1962) reported that H. nana, the dwarf tapeworm was widespread with an incidence of 0.1 - 7 per cent in the southern United States and the Latin American countries. Read's (1951) investigations of the "crowding effect" in tapeworm infections showing that the length of the worms is generally inversely proportional to the numbers present was confirmed in this study. The larger worms (300 mm) exceed the lengths quoted in many texts for this parasite but Chandler and Read (1961) do report comparable lengths.

H. nana's unique life cycle involving the omission of an intermediate host is well documented but the relationship between the rodent and human "strains" has been questioned with the result that those specimens from rodents are frequently referred to the species or sub-species fraterna. C.P. Read however reported readily infecting himself with cysticercoids of H. nana from mice (Chandler and Read, 1961 p.369). H. nana was also recovered from R. rattus collected from food preparation premises; both in Auckland and Christchurch.

H. nana was absent from M. musculus living in close proximity to infected R. rattus and R. norvegicus. Although infections have been recorded elsewhere in M. musculus the work of Larsh (1947) has shown that the time of passage for cysticeroids through the intestine of healthy mice is insufficient to allow establishment of this parasite.

Strobilocerci of Hydatigera taenaeformis were collected from R. norvegicus livers in and near Christchurch as well as from suburban and laboratory M. musculus there. Although one human infection has been reported (Chandler and Read, 1961 p.360) this is a cosmopolitan parasite of the domestic cat, Felis catus, and is recorded also from a range of Felidae and Mustelidae (Wardle and McLeod, 1952). In the rubbish dumps where infected hosts were collected several species of small mammals were observed and both cats and a ferret, Putorius putorius, were caught in cage traps.

E. TREMATODA

The occurrence of Plagiorchis muris in R. exulans from New Zealand is of interest in several ways. These are the first records of this parasite in New Zealand and are the first trematodes recorded here from the alimentary tracts of rodents. This trematode infests a wide range of hosts and an experimental infection in man has occurred (McMullen, 1937b). P. muris is reported from rats in Hawaii (Alicata, 1964), but the host species was not named. In New Zealand, as in Hawaii, several other known potential hosts of P. muris occur making determination of its introductory host difficult. Although R. norvegicus, a common host, is present on Kapiti Island it does not appear to ever have been on Cuvier Island. R. exulans is the most likely original host but the so-called Maori-dog, and the avian hosts cannot be disregarded. The original host must have presented the opportunity to find a suitable intermediate host(s) in the New Zealand invertebrate fauna. The diversity in the known intermediate hosts (Yamaguti, 1958) does however suggest that this may not have been difficult.

F. NEMATODA

Capillaria hepatica occurred primarily in R. exulans

(in 17 of the 53 examined). The presence of large masses of eggs from this parasite in an immature host (35 g.) shows that infection can, and does, occur while the hosts are very young. With R. rattus the presence of C. hepatica eggs only in Auckland is probably an indication of geographical limitation of the species rather than a low incidence as the R. exulans infected are all from localities adjacent to the Auckland province. In tropical Ponape Jackson (1962) found 50 percent of the R. norvegicus to be infected and about one fourth of the R. rattus and R. exulans. Despite extensive examinations no adult worms were collected. The difficulties in detecting and extracting the adult worms were outlined by Bancroft (1893) and the first two complete adult worms available for description (Wright, 1961) were collected from their host's abdominal cavity and not the liver.*

Capillaria ? sp. was presented in 34 of the 50 R. exulans in which the oesophagus was examined. This species also occurred in one R. rattus from Auckland City and two R. norvegicus from Whale Island (see page 63). Again a limited geographic distribution is apparent with all localities being in and around the Auckland province.

This nematode was found threaded in and out the oesophageal and stomach mucosa and was often present in the stomach on sloughed-off portions of mucosal tissue. This long fine worm proved very difficult to extract and few complete worms were obtained. No male worms were detected making specific identification impossible and the generic identification tentative. Marshall (1955) noted similar nematodes from Arno atoll where "one host (R. exulans) had a single long whipworm threaded through the mucosa (stomach); another had several such worms threaded in and out of the lining". Ash (1962) stated that very few species of Capillaria have been reported from the genus Rattus. The only capillariads recorded from the alimentary tract of rats are Capillaria sp. from R. norvegicus in Wisconsin, U.S.A., and C. traverae from R. rattus and R. norvegicus in Hawaii. The latter occurred in the small intestine (Ash, 1962).

Trichosomoides crassicauda was the only helminth restricted to R. norvegicus and had a wide distribution including both Kapiti and Campbell Islands as well as South

* Eggs from each of the three species of Trichuridae are shown in Appendix H.

Island localities (Table 48). This cosmopolitan parasite of R. norvegicus has been collected from the kidneys, ureters and bladder (Thomas, 1924). In this survey only the bladder was examined and the numbers recovered thus represent the bladder fauna.

Mastophorus muris has been previously recorded from New Zealand. Ford-Robertson and Bull (1966) reported this species from R. exulans and the nematode tentatively listed as Physalaptera getula by Beveridge and Daniel (1965), from R. norvegicus, has been subsequently identified as M. muris (M.J. Daniel, pers. com.). This cosmopolitan species has a wide range of rodent hosts. It is a large nematode and they were frequently present in large numbers, almost filling the distended stomachs of their hosts. In each of two adult R. exulans collected from Cuvier Island during November over 30 of these worms were recovered although, in both cases, several of these were present in the oesophagus and duodenum when examined. The distended nature of the stomachs made it unlikely that these other worms were all in these stomachs prior to the host's capture. M. muris occurred in R. rattus from several localities (Table 38) in both rural areas and city commercial premises. In R. norvegicus, however, it occurred only twice (Table 39), in both instances where this host was living in close proximity to one of the other Rattus species. Only one infection was in an immature host (R. exulans) and the number of worms was small (Table 37).

Nippostrongylus brasiliensis is a parasite of both R. rattus and R. norvegicus. Its extensive distribution is summarized by Haley (1961) and when this is considered its widespread occurrence in both of these hosts in New Zealand (Tables 46 and 47) is not unexpected. The literature of experimental parasitology based on this species is extensive and its usefulness has been adequately demonstrated by many authors. Yokogawa (1921) noted that this worm tended to congregate in the anterior portion of the small intestine and this tendency was repeated here. The degree to which its more extensive distribution in the more heavily infested hosts can be attributed to post-mortem movement in these hosts cannot be assessed. The regularity of their occurrence in all sections and the relatively great length of the small

intestine does however make it likely that these worms were present in the postior section during life. The pathogenic effects of these worms, both as larvae and adults, are well documented (Porter, 1935; Oldham, 1967) and no attempt was made during this survey to assess tissue damage by them or to detect larval stages within the lung tissue.

Heligmosomoides polygyrus occurs extensively in Western Europe and North America as a parasite of several rodent species including Mus musculus (Forrester, 1971). In this survey it has been recorded only from M. musculus. The range of habitats from which hosts were collected in Christchurch and North Canterbury suggest that it could be more widespread.

Syphacia obvelata is a cosmopolitan parasite of M. musculus and occurred in 35 of the 95 mice examined (Table 42) making it the most prevalent helminth from M. musculus. Although reported on many occasions from Rattus spp. the data presented by Hussey (1957) show that it is probable that these were misidentifications of Syphacia muris caused primarily by unqualified assumptions from characters of the female worms only.

The incidence of S. obvelata increased with host body weight, while the numbers per infected host decreased (Table 52) but this relationship was not consistent enough to produce a rank correlation. No pathological effects attributable to this parasite were observed but gross infections are often associated with various forms of gut malfunction (Oldham, 1967). The expulsion of live worms in faeces was observed in heavily infected laboratory hosts. More than 40 laboratory mice, additional to those in this survey, were examined specifically for this parasite. All but one of these were infected, often with between 100 and 200 worms filling the caecum and colon. As the eggs are deposited in the perianal region and development is direct (Hussey, 1957) the high host densities in laboratory stocks make reinfections more likely than in feral populations where a comparable number of S. obvelata was found only once.

Several publications discuss the taxonomic characters of S. obvelata, S. stroma and S. muris and the differences have been clarified by Morgan (1932), Khera (1954) and Hussey

(1957). The distinction between the species of Syphacia is based primarily on egg size and the characteristics of the males. As the sex ratios obtained in this survey show (p 63) the number of males recovered is considerably less than the females. The sex ratios published elsewhere and those obtained here cannot be safely compared. As the female worms are visible without magnification but the male worms require at least x 16 magnification to ensure their detection and as the methods of examination in other surveys are not known it is not certain whether the males could have been missed. Such omissions probably account for the lack of male Syphacia noted by Hussey (1957) in many of the surveys and descriptions. These low numbers of male worms (less than 8% in each host) may indicate a shorter life span with females being fertilised before reaching full size and the males then dying and being passed out. This view has been supported by Lewis (1968).

Heterakis spumosa was recovered widely from R. rattus (Table 44) and from the North Canterbury-Christchurch area in R. norvegicus (Table 45) and is a cosmopolitan parasite of both of these host species. Little is recorded on the biology of this nematode but Oldham (1967) noted that no visible gross pathology in experimentally infected laboratory mice or rats has been reported.

A distinctive feature of the infections by two of the nematode species was an apparent relationship between host body weight and the size of infection (see page 64).

Two of these correlations were significant at the 0.05 confidence level (Appendices C and D) and are thus strong indications of (1) an inverse relationship between R. exulans body-weight and S. muris numbers and (2) a positive correlation between R. norvegicus body-weight and N. brasiliensis numbers. While these were not significant at the 0.01 level the chances that these relationships above occurred are so high that larger samples could be expected to confirm these trends. In these samples at least, it is apparent that some host-resistance factor was operating in R. exulans to limit S. muris numbers as adult worms were found as frequently in the smaller hosts as in the larger ones.

The progression of infection size with host body-weight noted for N. brasiliensis suggests that the parasite population is increasing in proportion to some resource associated with host size. This may be one of several factors, e.g. diet (food quality), food quantity, increased host tolerance resulting from physiological responses to the parasites presence or it may be the consequence of the larvae from the initial infection having completed development in the lungs and moved into the small intestine, determination of this would however involve further investigations beyond the range of this study.

G. QUANTITATIVE ANALYSES

Consideration of the quantitative aspects of the parasite data collected for this survey involves an analysis of collection methods of both parasites and hosts. The ectoparasite detection levels given in Tables 16, 21 and 22 show variations in the size of ectoparasite samples collected by the three methods used. The direct comparison of the brushing and fur-dissolving technique used (Table 17) on R. rattus constitutes too small a sample to allow statistical comparison but is sufficiently impressive to suggest that the size differences between the samples from the three methods (Tables 16, 21 and 22) are the result of these collection methods and not the actual ectoparasite samples. Hopkins (1949) questioned the validity of most louse collection methods as bases for quantitative conclusions about both the fur fauna and the total ectoparasite populations. Although the fur dissolving techniques can ensure that the fur fauna at the time of collection is obtained the whole variety of ecological factors affecting both parasites and hosts require consideration.

The analysis of other than the anopluran portion of the fur fauna has been related to the practical difficulties posed by the techniques. The need for the use of fur-dissolving methods is exemplified by Wasylik's (1965) finding that even after 420 combings not all of the mites had been removed from a European hare. Hilton (1970) in attempting to adapt Buxton's (1934) and Hopkin's (1949) techniques for use on large numbers of small birds and mammals appears to have lost the advantages of these techniques through the

incorporation of extra steps into the procedure. Extra chances of parasite loss were thus introduced. A similar technique to that used in this survey has been outlined by Williams (1972). To allow detection of those arthropods rendered transparent by the KOH solution Williams utilised the stain acid-fuchsin. During this survey it was found that, for the smaller mites, examination by transmitted light under x 16 over a black base was sufficient to ensure detection.

The classical problem of ectoparasite surveys in attempting to assess the absolute number of ectoparasites in the host's habitat have been ignored in this survey as, in most cases, the bulk of the data necessary to determine host prevalence, and other population characteristics, were not available. The questions posed by Cole and Koepke (1946), as the result of their surveys and those of Rumreich (1945), cannot thus be answered. As noted by these authors the standard practice of translating parasite counts to indices of abundance requires certain adjustments to data and controls of survey procedures which the sources of material used here would not allow.

The utilisation of constant collection procedures is largely an avoidance or replacement, rather than a solution, of many of the problems in determing the influence of ecological factors on ectoparasite faunas. The use of live trapped animals to avoid the problems of parasites leaving a dead host introduces problems resulting from the "sweating" of parasites during the physiological responses of the hosts to their confinement. The physical restrictions in cage-trap placement and inspection would make a survey such as this considerably more involved and time consuming and beyond the resources normally available for such surveys.

The analysis of the fauna in each container in which hosts were received suggests that certain parasites do not leave their hosts in significant numbers. Although this determines only movement during the period between placement in container and examination, movement in the period between host capture (death) and placement in the container or plastic bag can be assumed to be similar. This being the consequence of those species mobile enough to leave the host carcass

while alive also being less firmly lodged in the host's skin or fur during immersion in preservative or plastic bag. Species which occur off the host in less than 5% of their numbers were the lice Hoplopleura pacifica and Polyplax spinulosa and the three myobiid mite species. With these five species, at least, satisfactory indications of the size of live-host populations can be determined from dead hosts. Although most of the fleas were recovered from the hosts fur 11 of 104 were collected from the containers from one locality and 11 of 24 in another. In the former case many fleas were collected from the external surface of the fur, the legs, tail and the string to the label on the hind leg of the host. Although fleas were observed to move to the surface of the fur of a heavily infested host (R. rattus) immediately it had been killed in the field, Elton (1931, 1934) stated that little difference in flea numbers (1.2 vs 1.7 fleas/host) was found between freshly killed mice and those dead for up to 10 hours. The factors determining flea movement from the comparative insulation of rodent fur will include both the amount of contact between the carcass and other rodents and the range of environmental factors. These will be different in each case and little is known of their roles.

The full significance of ectoparasite faunas on rodents in New Zealand will require determination of the habitats occupied by these hosts. With the knowledge of their habitat ranges the nature of the parasite faunas could then be related to the variety of factors characteristic of these habitats.

Conclusions from the quantitative data recorded for the helminth (endoparasitic) species have a better foundation. Post-mortem movement of helminths in rodents undoubtedly occurs. As no significant difference was apparent between the microhabitats of these species in hosts which had been freshly killed and those which had been dead for varying periods then such movements have been ignored. As with the fur fauna, extrapolations, from the data obtained, to the parasites of the total host populations require the qualifications imposed by the representativeness of the host samples utilised in terms of population characteristics and habitat ranges. Host collection methods are analysed in

Appendix A and although the variety of methods used might be expected to compensate for any inefficiencies of individual methods they were not spread evenly over the range of localities and habitats sampled. This problem of sample representativeness is not peculiar to this survey and host-collection method is not the only factor influencing it. As little published work on the population structures or habitats of New Zealand's rodent species is available the representativeness of the samples obtained cannot be assessed. Despite this common problem with the ectoparasite fauna the helminth fauna obtained from individual hosts is quantitatively "whole" and the numbers obtained can be accepted as those occurring in the living host prior to capture.

H. HOST SPECIFICITY

Considerable overlapping of the parasite-host relationships occurred among the hosts studied, in particular the three species of Rattus. Of the fleas only Xenopsylla cheopis and X. vexabilis were collected from one host species and the former is known to occur also on another rodent species in New Zealand. The differences between the mite faunas of Mus musculus and the Rattus species were quite pronounced. But in many cases the mite species present appeared to be a consequence of the host's habitat, rather than species, as has been outlined in the discussion of the normal habitats of both hosts and the mites included in categories B and C. The separation of the faunas of Mus and Rattus are clear in the category A mites. Radfordia ensifera is extensive on all three species of Rattus but the only myobiid mites recovered from M. musculus were Myobia musculi and R. affinis which in turn were restricted to this host. The remaining parasites in this category were Notoedres muris and Myocoptes musculinus. The latter has only been recorded from Mus musculus, in New Zealand, while Notoedres sp. has now been recorded from all three Rattus species. The presence of R. norvegicus on Kapiti Island where Sweatman (1962) recorded Notoedres sp. on R. exulans suggests that this will also be Notoedres muris introduced by R. norvegicus.

Host specificity was more evident in the lice. The

two records of Hoplopleura pacifica on R. norvegicus were both from Kapiti Island where this host co-exists with R. exulans, the normal host for this parasite. The remaining records of lice consist of Polyplax spinulosa entirely on R. norvegicus and R. rattus, P. serrata on M. musculus and H. pacifica on R. exulans. As discussed earlier the solitary record of P. spinulosa on R. exulans must be considered as a contamination obtained after capture and removal to Lower Hutt.

Rausch (1957), in an analysis of the helminth parasites of several North American microtine rodent species, found that although their helminths demonstrated highly developed phylogenetic specificity few showed any evidence of host specificity at the generic level. Among the nematodes recovered in this survey a clear distinction occurred between those infecting Rattus and Mus. Heligmosomoides polygyrus and Syphacia obvelata occurred only in M. musculus and the remainder occurred only in Rattus. Of these only Trichosomoides crassicauda was restricted to a single host species (R. norvegicus). Although Capillaria ? sp. had a very limited occurrence in R. norvegicus and R. rattus this may be the result of the geographic separations of the host samples examined.

Hymenolepis nana occurred only in R. rattus and R. norvegicus but is known overseas as a parasite of M. musculus. The occurrence of H. diminuta in all four host species and the strobilocerci of Hydatigera taenaeformis in R. norvegicus and M. musculus, show that host-specificity is not great in the cestodes and the host records of all three of these parasites show a wide range of recorded species.

Yamaguti (1961) lists an extensive range of host species for the trematode Plagiorchis muris. Its occurrence in R. exulans from two widely separated localities (Kapiti and Cuvier Islands) suggests that between these two at least it was widely distributed in the past. If not in the rodent species at present occupying the area then in R. exulans prior to its replacement. P. muris is reported as a parasite of both R. rattus and R. norvegicus and its apparent absence from these hosts in New Zealand is difficult to explain. A possibility is that the intermediate host to definitive host step has not been completed because of diet differences

between R. exulans and these two species. The known intermediate hosts include a mollusc, a midge and an amphipod but further work is necessary to determine the intermediate (and other definitive) hosts of this trematode in New Zealand.

I. ECONOMIC AND MEDICAL SIGNIFICANCE OF THE PARASITE FAUNA

The economic and medical relevance of rodents and their parasites have been widely discussed. Wodzicki (1950) and Watson (1959) summarized the economic importance of rats and mice in New Zealand and quoted many examples of their damage. The medical importance of rodents and their parasites have been largely inferred from overseas studies, with only the Plague (McLean, 1955) and Salmonella studies (Blakelock and Allen, 1959; Robinson and Daniel, 1968) occurring in the literature in recent years.

Of the metazoan parasite species recovered which are likely to be considered of economic or medical importance the two species of Hymenolepis were the most widespread. These species occurred in relatively close contact with man or his foodstuffs and thus formed potential sources of human infections.

Ectoparasites are seldom a primary or sole cause of death. Their pathological significance is therefore more often associated with their ability to act as vectors of other microbial or parasitic diseases. Information concerning ectoparasites as disease vectors is fairly well documented and both the general direct and indirect effects of parasites on their hosts have been well summarized by Sprent (1963).

The ectoparasite which has created the most interest in the literature is the Oriental Plague flea Xenopsylla cheopis. The great overlapping of flea-host relationships noted by Elton (1931) is particularly important in the spread of endemic diseases and the presence of X. cheopis in Auckland is of significance in determining the capacity of Auckland's rodent populations to act as reservoirs and vectors for the Plague should its reintroduction ever occur. The restriction of this flea to Auckland cannot be assumed as Newstead and Evans (1921) have shown that its distribution throughout artificially heated premises can be extensive.

X. cheopis is not the only flea capable of Plague transmission and Plague is not the only human disease transmitted by rat fleas but its primary role in Plague transmission emphasises the need for greater knowledge of its incidence and distribution in New Zealand.

Among the nematode species detected only Capillaria hepatica is a likely human parasite. This species is nearly cosmopolitan and exhibits broad host tolerance with both genuine and spurious human infections having been reported (Layne, 1968). Details of its transmission are given by Weidman (1925) and this species incidence is also of importance to agriculturalists. Although one human infection by Syphacia obvelata has been reported (Riley, 1920) this appears to be an isolated case. During this survey no evidence was found of either Trichinella spiralis to supplement Cairns' (1966) records or Angiostrongylus cantonensis previously investigated in New Zealand by Alicata and McCarthy (1964).

Many of the economically important animals recovered in this survey were the category C mites and the other non-parasitic arthropods found in the fur. The distribution and incidence of Glycyphagus destructor have been widely investigated and it is one of the commonest species of stored-product mites living in stores of grain, cereals, dried fruit etc. and also in rodent nests, which Hughes (1961) suggest may be its natural habitat. The economic importance of G. destructor is outlined by Sinha (1963). Acarus species are common pests of grain and grain products and Kleemania speices are also frequently encountered on stored products.

The occurrence of the weevil Siophilus oryzae on R. rattus from grain stores in Christchurch and other weevils and grain beetles (Coleoptera) from both Christchurch and Auckland show, with the previously discussed mite species, that this host and M. musculus in particular, can be responsible for infestations of these pests. The Dermestid larvae collected from the same habitat may also represent another stored-product pest being carried on R. rattus. R. rattus and M. musculus are very prevalent in grain stores and food storage premises in New Zealand and their mobility, illustrated by their rapid re-infestations following poison

programmes and fumigations, makes them very efficient, and probably significant, vectors for stored product pests. The tropical rat mite, Bdellonyssus bacoti which was reported attacking man in New Zealand (Lamb, 1952) was not collected in this survey.

J. SOURCES OF THE RODENT-PARASITE FAUNAL COMPONENTS

These lists (Table 53) have been compiled from the present levels of incidence of parasite species and the known records both overseas and in New Zealand. The host species are listed with the parasite species probably introduced into New Zealand with them.

Both C. hepatica and H. taenaeformis may also have been introduced in other hosts. C. hepatica has been reported from many wild and domestic mammals. Although Cuvier Island has been partially grazed in the past the presence of infected R. exulans on both Burgess and the Hen and Chicken Islands supports its introduction in this host. The origin of the infected R. rattus in Auckland cannot be so easily supported because of their greater opportunities for inter-specific contacts with other host species.

Hydatigera taenaeformis has both the cat and mustelids as potential definitive hosts in New Zealand and after consideration of the chance of an infected host being eaten by these predators, it has been concluded that this cestode must have been introduced in one of its definitive hosts.

The origins of the Siphonaptera, Anoplura, Acarina, Trematoda, Cestoda and Nematoda have all been considered in the discussion on each of these groups. In the consideration of the parasite fauna of R. exulans, four localities where no other rodent species are known to have been present gave "uncontaminated" host populations, i.e. Burgess, Cuvier, Red Mercury and Little Barrier Islands. The fauna of the latter locality is confirmed in part by Ford-Robertson and Bull (1966). For the other host species no localities can be confidently accepted as having been invaded by only one rodent species although evidence to the contrary is lacking from the sub-antarctic islands sampled.

The lack of reliance of the category B and C mites on

Table 53 PROBABLE INTRODUCTORY HOSTS OF RODENT PARASITES IN NEW ZEALAND

Parasite species	Rodent species R. exulans	R. rattus	R. norvegicus	M. musculus
Siphonaptera				
Nosopsyllus fasciatus	X	X	X	
Leptopsylla segnis		X		X
Xenopsylla cheopis		X		
Xenopsylla vexabilis	X			
Pygiopsylla hoplia	X		X *	
Anoplura				
Hoplopleura pacifica	X			
Polyplax spinulosa		X	X	
Polyplax serrata				X
Acarina (Category A)				
Radfordia ensifera	X	X	X	
Radfordia affinis				X
Myobia musculi				X
Notoedres muris		X	X	
Myocoptes musculinus				X
Cestoda				
Hymenolepis diminuta	X	X	X	
Hymenolepis nana		X	X	
Trematoda				
Plagiorchis muris	X			
Nematoda				
Mastophorus muris	X	X		
Nippostrongylus brasiliensis		X	X	
Syphacia obvelata				X
Syphacia muris	X	X		
Heterakis spumosa		X	X	
Heligmosomoides polygyrus				X
Trichosomoides crassicauda			X	
Capillaria ? sp.	X			
Capillaria hepatica	X	X		

* Heathcote record only.

their rodent hosts warrants their exclusion from these lists as any locality where rodents have been sampled is subject to mans' influences and thus these mites as a consequence. The record of Eulaelaps stabularis on R. exulans trapped in the lighthouse fowl-run on Cuvier Island probably resulted from an introduction with foodstuffs.

K. DETERMINANTS OF THE PARASITE FAUNA

The only metazoan parasite groups found elsewhere on rodents, and not recovered here, were the Acanthocephala and the ticks (Ixodes). The one tick obtained was a bird parasite and thus probably a straggler. The number of flea species infesting rodents is surprisingly small. Smit (1957) reports 20 flea species from the three "domestic" rodent species (R. rattus, R. norvegicus and M.musculus) in Great Britain while on these hosts in New Zealand only six flea species have been collected. Prolonged sea transport is unlikely to have had a direct "quarantine" effect on these hosts and three of five species normally infesting rodents in New Zealand were probably introduced on R. exulans. This host introduction is normally accepted as being the result of carriage in Polynesian vessels where even stricter quarantine conditions would have applied than occurred in the larger European ships.

The range of hosts infested by most flea species appears to be a reflection of the inter-specific contacts of the hosts rather than equal suitability of these hosts for parasitism. In New Zealand, and on board ships, inter-specific contacts between small mammal species are considerably reduced suggesting that the extent of a host's flea fauna is proportional to the variety of other related host species present in any region. This phenomenon cannot be expected to be restricted to the Siphonaptera. The helminth fauna was not extensive but the additional determinant of suitable intermediate hosts occurs here. Most of the helminths recorded from rodents in New Zealand are transmitted directly i.e. without utilising an intermediate host. Although Hymenolepis diminuta was extensive all four of its host species were infested by Nosopsyllus

fasciatus, one of its known intermediate hosts. The trematode Plagiorchis muris, as discussed earlier, has a wide range of known intermediate and definitive hosts.

Oldham's (1931) list of rodent parasites and the surveys which have been completed in most countries show extensive and varied parasite faunas. The combination of host species in New Zealand occurs, in the absence of other rodents, only in Hawaii. The total metazoan parasite fauna of all three Rattus species and the ectoparasites of Mus musculus there have been listed by Ash (1962) and Alicata (1964). Few differences occur between the faunas collected in both regions (Table 54). Of those species occurring in New Zealand only three (or four?) helminths and three arthropods are not present in Hawaii while H. polygyrus (and S. obvelata ?) may be present in M. musculus. Of the 8 helminths found in Hawaii but not in New Zealand two of the trematodes and three of the nematodes require Gastropoda, Orthoptera or Coleoptera intermediate hosts. The separation of these from the definitive host during passage to New Zealand and/or the absence of these or other suitable intermediate hosts would account for their absence. All of the arthropod parasites listed as present in Hawaii have been recorded in New Zealand.

With only two of the parasite species present on "domestic" rats in New Zealand likely to have been derived from R. exulans or other rodent species, the fauna from these hosts is likely to be comparable to that of populations of these host species elsewhere which have been subjected to similar quarantine conditions and restrictions in their inter-specific contacts with other rodents. A comparison of the fauna for laboratory rodents (R. rattus, R. norvegicus, M. musculus) in the Northern Hemisphere (predominantly U.S.A.) and for these hosts in New Zealand shows 24 species in common and eight different (Table 55). Seven of these eight are absent from New Zealand and the development of two of these is again indirect. The Northern Hemisphere laboratory list has been compiled from those of Oldham (1967), Hussey (1957), Ewing (1938), Flynn (1963) and Forrester (1971). This similarity in faunas has occurred despite great differences in the habitats of laboratory and

Table 54 COMPARISON OF THE METAZOAN PARASITE FAUNA RECORDED FROM *RATTUS EXULANS*, *R. RATTUS*, *R. NORVEGICUS* AND *MUS MUSCULUS* IN HAWAII AND NEW ZEALAND.

Parasites	R = recorded Hawaii	New Zealand
Siphonaptera (omitting stragglers)		
Leptopsylla segnis	R	R
Nosopsyllus fasciatus	R	R
Pygiopsylla hoplia	-	R
Xenopsylla cheopis	R	R
Xenopsylla vexabilis	R	R
Anoplura		
Polyplax serrata	-	R
Polyplax spinulosa	R	R
Hoplopleura pacifica	R	R
Acarina (Category A)		
Myobia musculi	R	R
Radfordia affinis	R	R
Radfordia ensifera	R	R
Myocoptes musculinus	R	R
Notoedres muris	-	R
Acanthocephala		
Moniliformis moniliformis	R	-
Cestoda		
Hymenolepis diminuta	R	R
Hymenolepis nana	R	R
Hydatigera taenaeformis (strobilocerci)	R	R

Table 54 (Cont'd)

Parasites	R = recorded Hawaii	New Zealand
Trematoda		
Plagiorchis muris	R	R
Echinostoma sp.	R	-
Centrocestus formosanus	R	-
Stellantchasmus falcatus	R	-
Nematoda		
Mastophorus muris	-	R
Heterakis spumosa	R	R
Syphacia obvelata	*	R
Syphacia muris	*	R
Heligmosomoides polygyrus	-	R
Trichinella spiralis	R	R
Capillaria hepatica	R	R
Capillaria ? sp.	-	R
Capillaria traverae	R	-
Trichosomoides crassicauda	R	R
Nippostrongylus brasiliensis	R	R
Angiostrongylus cantonensis	R	-
Strongyloides ratti	R	-
Physaloptera muris-brasiliensis	R	-
Gongylonema neoplasticum	R	-

* Alicata (1964) reported no specific survey of the helminths of *Mus musculus* and listed *Syphacia obvelata* from "Rat". This is almost certainly *S. muris* (see Hussey, 1957).

Table 55 COMPARISON OF THE PARASITE FAUNA RECORDED FROM *RATTUS RATTUS*, *R. NORVEGICUS* AND *MUS MUSCULUS* IN LABORATORY STOCKS IN U.S.A. AND FERAL POPULATIONS IN NEW ZEALAND.

Parasite	R = recorded Laboratory fauna (U.S.A.)	New Zealand fauna
Cestoda		
Hymenolepis diminuta	R	R
Hymenolepis nana	R	R
Hydatigera taenaeformis (strobilocerci)	R	R
Nematoda		
Mastophorus muris	-	R
Heterakis spumosa	R	R
Aspicularis tetraptera	R	-
Syphacia obvelata	R	R
Syphacia muris	R	R
Heligmosoides polygyrus	R	R
Trichinella spiralis	R	R
Capillaria hepatica	R	R
Trichosomoides crassicauda	R	R
Nippostrongylus brasiliensis	R	R
Angiostrongylus cantonensis	R	-
Gongylonema neoplasticum	R	-
Acanthocephala		
Moniliformis moniliformis	R	-

Table 55 (Cont'd)

Parasite	R = recorded Laboratory fauna (U.S.A.)	New Zealand fauna
Siphonaptera		
Leptopsylla segnis	R	R
Nosopsyllus fasciatus	R	R
Ctenophthalmus agyrtes	R	-
Xenopsylla cheopis	R	R
Anoplura		
Polyplax serrata	R	R
Polyplax spinulosa	R	R
Hoplopleura pacifica	R	R
Acarina (Category A)		
Echinolaelaps echidninus	R	-
Psorergates simplex	R	-
Myobia musculi	R	R
Radfordia affinis	R	R
Radfordia ensifera	R	R
Myocoptes musculinus	R	R
Myocoptes romboutsi	R	-
Notoedres muris	R	R

New Zealand rodents and supports availability of intermediate hosts and inter-specific contacts with other rodent species as the major determinants of these faunas.

The absence of the cosmopolitan genus Laelaps among the category B mites is surprising and although the range of mites collected suggests that many more species are present, members of this genus frequently occur in great numbers in rodent parasite surveys. The category B and C mites along with much of the other fur fauna appear to bear a cosmopolitan relationship with specific habitats within their hosts' ranges and comprise overlapping samples of the arthropod fauna of these habitats. They will serve as useful indications of the habitat ranges of their hosts in New Zealand.

CHAPTER 5

SUMMARY

1. Rodents were collected from 22 localities in New Zealand, including off-shore and sub-Antarctic islands.

2. 317 rodents (53 Rattus exulans, 68 Rattus rattus, 60 Rattus norvegicus and 136 Mus musculus) were examined for ectoparasites and 273 of these (53 R. exulans, 68 R. rattus, 57 R. norvegicus and 95 M. musculus) were examined for metazoan endoparasites. Pooled collections of ectoparasites from several hosts were also obtained and examined.

3. A variety of ecto- and endo-parasite collection methods were used and evaluated.

4. Five species of Siphonaptera, three species of Anoplura, more than 26 species of Acarina and a variety of other arthropoda were collected from hosts' fur and skin. Nine species of Nematoda, three species of Cestoda and one species of Trematoda were collected from the internal organs. 25 of these 47 + species have not been previously recorded in New Zealand.

5. The distribution and incidence of each parasite species recovered are presented and factors influencing these are discussed.

6. The significance of the quantitative data collected and the efficiencies of all parasite collection methods are discussed.

7. The parasite assemblages of each host are presented and discussed particularly in relation to host specificity and the faunas of these hosts elsewhere.

8. The economic and medical importance of the parasite fauna is considered.

9. The probable origins and introductory hosts for each parasite species are considered.

10. Comparable situations elsewhere are discussed and used to illustrate the factors determining the rodent parasite faunas present in New Zealand.

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PERSONS AND ORGANISATIONS ASSISTING IN HOST COLLECTION

Collection station (Fig. 2)	Locality	
1	Burgess I.	Mr R. Wallace. Principal lighthouse keeper.
2	Hen and Chickens	Mr M.J. Daniel. Ecology Division, D.S.I.R.
3	Goat I. (Leigh)	Mr D. Bettesworth. Zoology Dept., Univ. of Auckland.
4	Little Barrier I.	Ranger Wisnesky. Hauraki Gulf Maritime Park.
5	Cuvier I.	Mr B. Woolcott. Principal lighthouse keeper.
6	Auckland City	Mr J. Marsden. Boracure Auckland Ltd.
7	Motukawao Gp.	Mr G.R. Veitch. Wildlife Div., Dept. Int. Affairs.
8	Red Mercury I.	Mr G.R. Veitch.
9	Whale I.	Mr D. Bettesworth.
10	Mt Bruce Reserve	Mr C.D. Roderick. Dept. Int. Affairs.
11	Kapiti I.	Mr M.J. Daniel.
12	Inangahua	Dr Cook, Dept. of Agriculture (Christchurch).
13	Lake Taylor	Mrs F.R. Allison
14	Christchurch	S.B. Lambie Ltd., Christchurch City Council and numerous individuals.
15	North Canterbury	
16	Quail I.	
17	McKenzie Country	Mr J. Jolly. Zoology Dept., Univ. of Canterbury.
18	Timaru	S.B. Lambie Ltd.
19	Dunedin	S.B. Lambie Ltd.
20	Auckland Is.	Mr R. Taylor. Ecology Division D.S.I.R.
21	Campbell I.	
22	Antipodes I.	

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APPENDIX A

CAUSES OF HOST DEATH

R. exulans

Collection station no.	1	2	4	5	8	11	Total
Snap Traps	7	-	4	33	5	3	52
Natural causes	-	1	-	-	-	-	1
All causes	7	1	4	33	5	3	53

R. rattus

Collection station no.	3	6	10	12	13	14	16	18	19	Total
Snap Traps	2	1	7	3	1	13	4	-	-	31
Natural causes	-	-	-	4	-	-	-	-	-	4
Fumigation	-	4	-	-	-	-	-	9	-	13
By hand	-	-	-	-	-	7	-	-	-	7
Chloroformed in trap	-	-	-	-	-	4	-	-	-	4
Shot	-	-	-	-	-	-	1	-	-	1
Poisoned	-	-	-	-	-	5	-	-	3	8
All causes	2	5	7	7	1	29	5	9	3	68

R. norvegicus

Collection station no.	9	10	11	14	15	17	21	Total
Snap Traps	3	9	7	21	7	1	3	51
By hand	-	-	-	-	4	1	-	5
Chloroformed in trap	-	-	-	-	1	-	-	1
Shot	-	1	-	-	-	-	-	1
Poisoned	-	-	-	1	-	1	-	2
All causes	3	10	7	22	12	3	3	60

M. musculus

Collection station no.	14	15	16	17	18	20	22	Total
Snap Traps	61	28	3	-	-	3	3	98
Fumigation	12	-	-	-	4	-	-	16
By hand	21	-	-	1	-	-	-	22
All causes	94	28	3	1	4	3	3	136

APPENDIX B

EXAMINATION METHODS

Ectoparasite collection

Method	Host species				All Hosts
	R. exulans	R. rattus	R. norvegicus	M. musculus	
Brushed etc.	-	18	22	117	157
Hilton's	-	9	5	-	14
Potassium hydroxide (Buxton/Hopkins)	53	41	33	19	146
	53	68	60	136	317

Endoparasite collection

Examination of Alimentary system

Method	R. exulans	R. rattus	R. norvegicus	M. musculus	All Hosts
Gut dissected	-	9	10	75	94
Gut washed	53	59	47	20	179
	53	68	57	95	273

Extent of internal examination

	R. exulans	R. rattus	R. norvegicus	M. musculus	All Hosts
All organs examined	50	42	29	16	137
All except oesophagus examined	3	24	22	16	65
All except thoracic organs examined	-	2	6	63	71
	53	68	57	95	273

APPENDIX C

INFECTION LEVELS OF *SYPHACIA MURIS* IN *RATTUS EXULANS*

Host body-weight (in grams)	Rank	Number of *Syphacia muris*	Rank	D	D^2
26	1	691	1	0	0
63	2	53	4	-2	4
73	3	93	2	1	1
74	4	23	6	-2	4
80	5	12	8	-3	9
98	6	58	3	3	9
105	7	18	7	0	0
110	8	5	10	-2	4
128	9	31	5	4	16
138	10	10	9	1	1
					$\Sigma D^2 = 48$

$$\text{Spearman - Rho rank correlation } (\rho) = 1 - \left[\frac{6\ \Sigma D^2}{N(N^2-1)}\right]$$

$$= 1 - \left[\frac{288}{10(100-1)}\right]$$

$$= 1 - \left[\frac{288}{990}\right]$$

$$= 1 - 0.291$$

$$= 0.709$$

APPENDIX D

INFECTION LEVELS OF *NIPPOSTRONGYLUS BRASILIENSIS* IN *RATTUS NORVEGICUS*

Host body-weight	Rank	Number of *N. brasiliensis*	Rank	D	D^2
41	1	4	7	-6	36
44	2	4	7	-5	25
46	3	1	1.5	1.5	2.25
60	4	1	1.5	2.5	6.25
98	5	3	4	1	1
138	6	4	7	-1	1
148	7	66	14	-7	49
195	8	7	9	-1	1
219	9	93	15	-6	36
220	10	46	12	-2	4
226	11	3	4	7	49
284	12.5	43	11	1.5	2.25
284	12.5	51	13	-0.5	0.25
293	14	3	4	10	100
317	15	35	10	5	25
327	16	345	17	-1	1
330	17	114	16	1	1
					ΣD^2 340

$$\text{Spearman - Rho rank correlation } (\rho) = 1 - \left[\frac{6\ \Sigma D^2}{N(N^2-1)}\right]$$

$$= 1 - \left[\frac{2040}{4896}\right]$$

$$= 1 - 0.416$$

$$= 0.584$$

APPENDIX E

MONTHLY INCIDENCE OF HELMINTHS IN *RATTUS EXULANS*

Month	Jan	Apr	Jun	Aug	Sept	Nov
No. rats examined	6	1	21	12	3	10
H. diminuta	0	1	5	4	0	1
P. muris	1	0	0	0	2	0
M. muris	3	1	18	2 - 7*	1	4
S. muris	5	0	0	1	3	1
Capillaria ? sp.	5	0	15	10	0	4
C. hepatica	2	1	11	1	0	2

* Pooled stomach contents containing *M. muris* were received from five hosts.

MONTHLY INCIDENCE OF HELMINTHS IN *RATTUS RATTUS*

Month	J	F	M	A	M	J	J	A	S	O	N	D
No. rats examined	1	2	6	13	14	1	1	0	14	10	2	4
H. diminuta	0	0	0	1	2	0	0	-	0	1	0	0
H. nana	0	0	1	0	4	0	0	-	0	0	0	4
M. muris	0	1	0	0	4	0	0	-	6	0	0	0
N. brasiliensis	0	1	0	0	3	0	1	-	5	4	0	0
S. muris	0	0	3	10	3	1	1	-	7	3	1	1
H. spumosa	0	0	1	0	1	1	1	-	1	2	1	2
Capillaria ? sp.	0	0	0	0	0	0	0	-	1	0	0	0
C. hepatica	0	0	0	0	0	0	0	-	0	0	0	3

MONTHLY INCIDENCE OF HELMINTHS IN *RATTUS NORVEGICUS*

Month	F	M	A	M	J	J	A	S	O
No. rats examined	2	15	20	1	1	1	3	12	3
H. diminuta	0	5	0	0	0	0	0	0	0
H. nana	1	9	0	0	0	0	0	1	0
H. taenaeformis	0	4	1	0	0	0	0	0	0
M. muris	0	0	0	0	0	1	0	1	0
N. brasiliensis	0	5	4	0	0	0	1	7	0
S. muris	0	0	0	0	0	0	0	1	0
H. spumosa	0	5	0	0	0	0	0	1	0
Capillaria ? sp.	0	0	0	0	0	0	0	0	2
C. hepatica	0	4	2	0	0	0	1	0	0

MONTHLY INCIDENCE OF HELMINTHS IN *MUS MUSCULUS*

Month	J	F	M	A	M	J	J	A	S	O	N
No. mice examined	1	5	20	37	17	9	3	0	0	3	1
H. diminuta	0	0	0	3	0	0	0	-	-	0	0
H. taenaeformis	0	0	0	0	0	1	0	-	-	1	0
S. obvelata	0	2	5	16	9	0	1	-	-	2	1
H. polygyrus	0	0	1	1	6	1	1	-	-	0	0

APPENDIX F

SEX COMPOSITION OF ALL FLEA HOST SAMPLES

Host Species	No. females examined	No. females infected	No. males examined	No. males infected	Chi^2 Probability 1:1
R. exulans	24	9	29	15	>0.25
R. rattus	39	14	29	7	>0.25
R. norvegicus	26	6	34	7	>0.75
M. musculus	71	19	65	14	>0.50

APPENDIX G

SEX COMPOSITION OF ALL FLEA SAMPLES

Flea species	M	F	?*	Total	Probability 1:1 (Chi^2)
Leptopsylla segnis	39	100	3	142	< 0.001
Nosopsyllus fasciatus	117	126	2	245	> 0.500
Pygiopsylla hoplia	37	28	3	68	> 0.250
Xenopsylla vexabilis	3	0	0	3	-
Xenopsylla cheopis	3	2	2	7	-

* Damaged.

APPENDIX H

EGGS OF THE THREE SPECIES OF TRICHURIDAE (NEMATODA) COLLECTED

Plate 1. Eggs of *Trichosomoides crassicauda* (Bellingham 1840) (from worm).

APPENDIX H

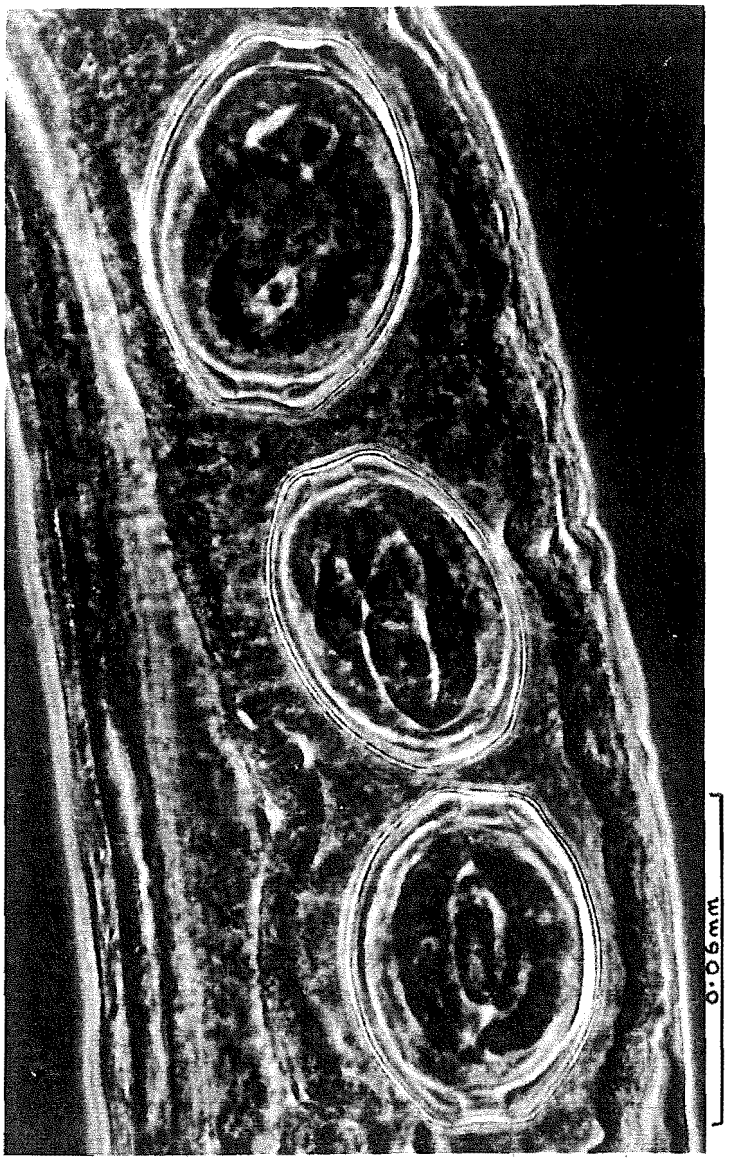


Photo : F. McGregor

Plate 2. Eggs of Capillaria hepatica (Bancroft 1893) (from host liver).

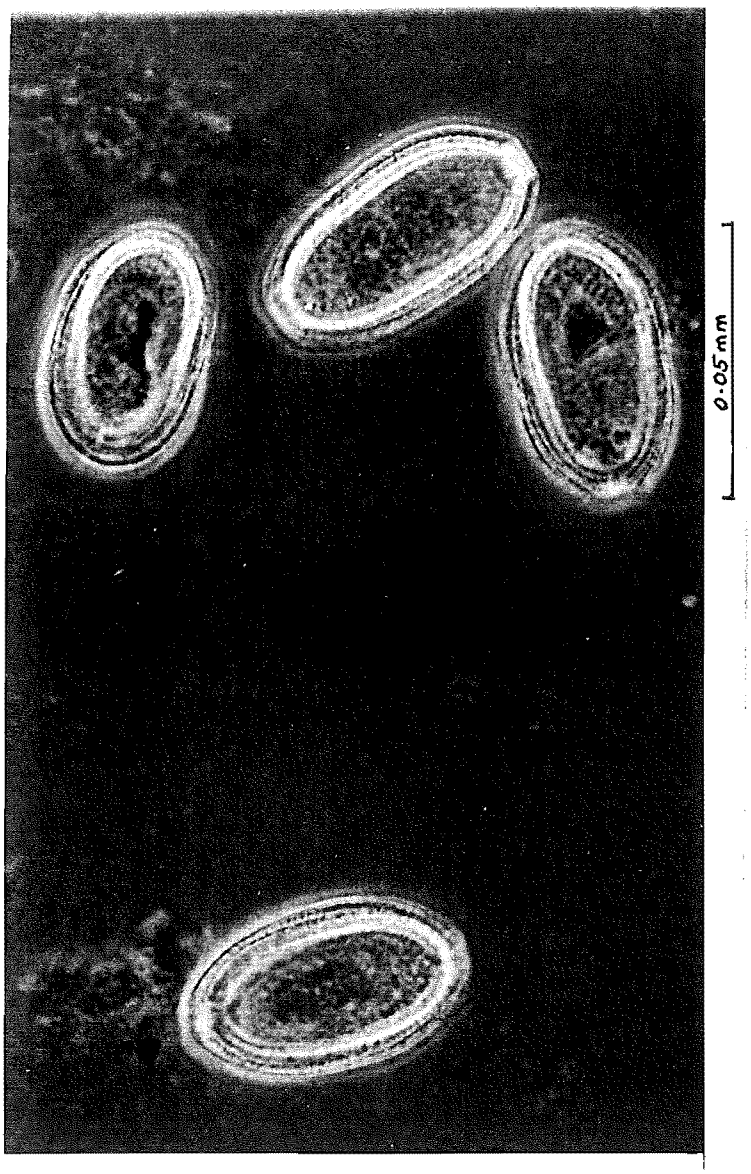
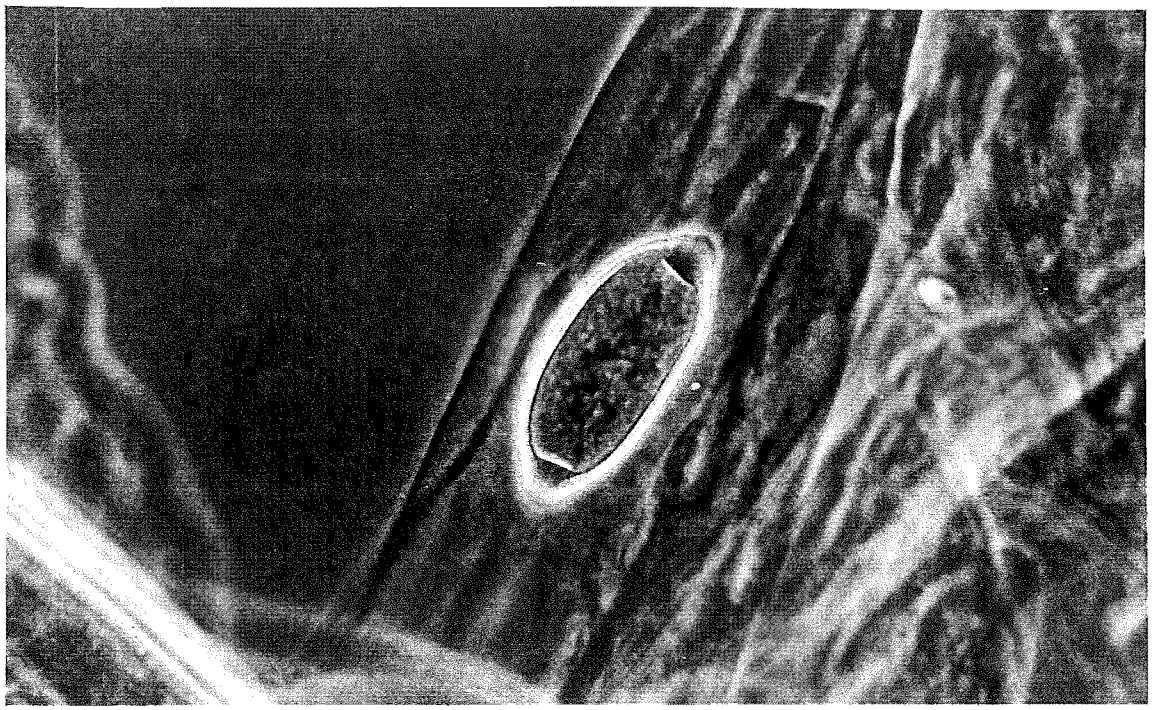


Photo : F. McGregor

Plate 3. Eggs of *Capillaria* ? sp. (from worm).



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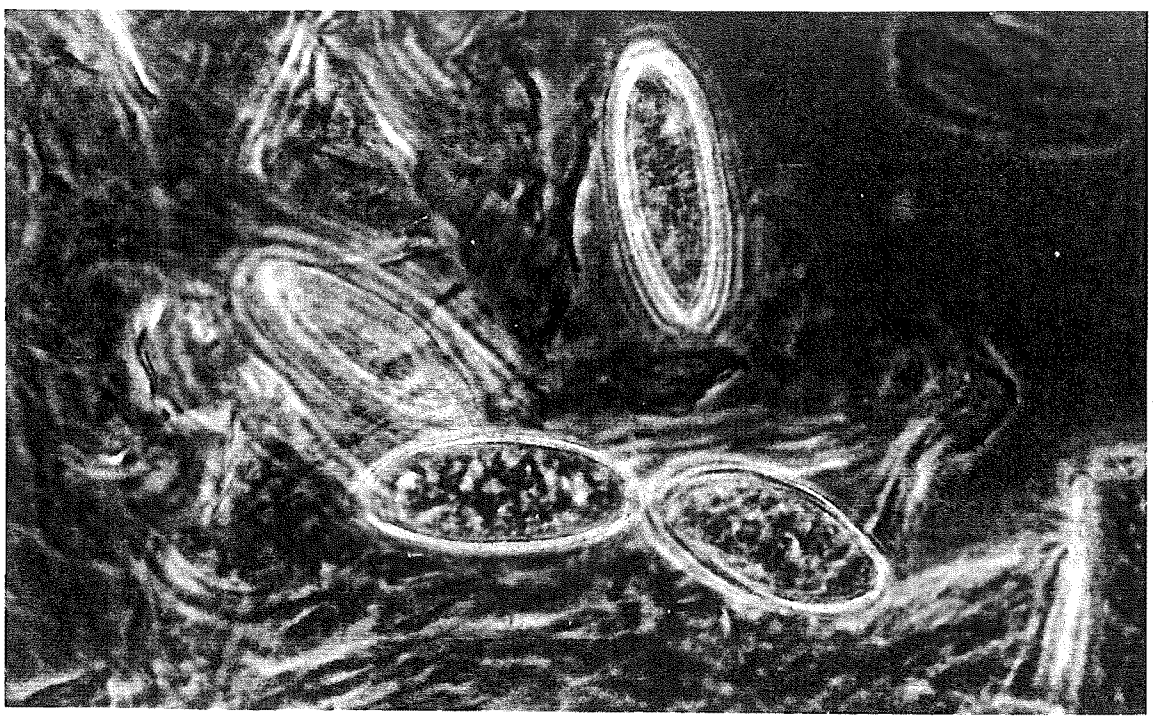

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Photos : F. McGregor